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兵庫農科大学研究報告

第4巻 第1号

自然科学編

THE SCIENCE REPORTS
OF THE
HYOGO UNIVERSITY OF AGRICULTURE

Vol. 4 No. 1

Series: Natural Science

兵庫農科大学

昭和34年

Sasayama, Hoygo, Japan

1959

目　　次

石田　裕：日本産ガガンボ科目録及び属，亜属の検索 V（英文）…… 1

福沢文雄：原子核内の古典的流束（英文）…… 12

石井健三・岸本昇三：単分子膜法による卵アルブミンと
ブロムフエノールブルウとの結合について…… 17

石井健三・安田勝幸：変性ペプシンの研究（補遺）…… 21

CONTENTS

ISHIDA, H. : The Catalogue of the Japanese Tipulidae,
With the Keys to the Genera and Subgenera (Diptera).
V. Limoniinae, Tribe Hexatomini. 1

FUKUZAWA, F. : Classical Flux in Atomic Nucleus. 12

ISHII, K. and KISHIMOTO, S. : Effect of Brom Phenol Blue
in Aqueous Substrate upon the Monolayer of
Ovalbumin. 17

ISHII, K. and YASUDA, K. : Studies on the Denatured
Pepsin (Supplement). 21

THE CATALOGUE OF THE JAPANESE TIPULIDAE, WITH THE KEYS TO THE GENERA AND SUBGENERA (Diptera)

V. LIMONIINAE, TRIBE HEXATOMINI

Hiroshi ISHIDA

I wish to express my cordial gratitudes and appreciation to Dr. Charles P. ALEXANDER, Amherst, U. S. A., for his continued aid and encouragement and for his kind information concerning my troublesome questions. Further, I wish to acknowledge my indebtness to Prof. Yoshijiro SAKURAI, the Hyogo University of Agriculture, Sasayama, who afforded me kind facilities for publishing this catalogue and also to Prof. Yasunobu YASUE and Mr. Kazuo KAWADA, the Ôhara Institute for Agricultural Biology, Okayama University, Kurashiki, for their kind aids in literature. Finally, my hearty thanks are also due to Messrs. Masafumi OHKURA, Kobe, Fumiki TAKAHASHI, the Kyoto University, Kyoto, and Kazuo TANAKA, Tokyo, for their kind aids.

List of Abbreviations (I)

AESA: Annals of the Entomological society of America.
AM: Annals and magazine of natural history.
ANMW: Annalen des naturhistorischen Museums in Wien.
ASEF: Annales de la Société entomologique de France.
AZ: Arkiv för zoologi.
BBES: Bulletin of the Brooklyn entomological society.
BCSS: Bulletin. Connecticut State geological and natural history survey.
BEZ: Berliner entomologische Zeitschrift.
CE: Canadian entomologist.
EM: Entomological magazine, Kyoto.
FA: Fauna Austriaca. Die Fliegen (Diptera).
FBI: Fauna of British India, including Ceylon and Burma. Diptera: Nematocera.
FF: Faune de France. Diptères: Tipulidae.
FG: The families and genera of North American Diptera (by C. H. CURRAN).
HIBI: Handbooks for the identification of British insects, IX (2) Diptera: Nematocera.
HNI: Suites à Buffon. Histoire naturelle des insectes. Diptères.
IIJ: Iconographia insectorum japonicorum.
IIM: Insecutor inscitiae menstruus.
JNES: Journal of the New York entomological society.
LSJ: Lingnan science journal.
MCAS: Memoir. Cornell University Agricultural Experiment Station.
MD: Monographs of the Diptera of North America.
NEC: Notes d'entomologie chinoise.
PAP: Proceedings of the Academy of natural sciences of Philadelphia.
PDI: Prodromus. Dipterologiae italicae.
PJS: Philippine journal of science.
PLSN: Proceedings of the Linnean society of New South Wales.
PUNM: Proceedings of the United States National museum.
RIM: Records of the Indian museum.
SB: Systematische Beschreibung der bekannten europäischen zweiflügeligen Insekten (pagination in brackets of Theil I, according to the "zweiter unveränderter Abdruck" in 1851.).
TAES: Transactions of the American entomological society.
TE: Tijdschrift voor entomologie.
TES: Transactions of the Entomological society of London.
TIJA: Thousand insects of Japan, Additamenta.
TM: Tierwelt Mitteleuropas, 6, iii Teil, 2 Lief., XVI.
TSBE: Transactions of the Society of British entomology.
TSES: Transactions of the Shikoku entomological society.
WEM: Wiener entomologische Monatschrift.
ZJ: Zoologische Jahrbücher. Abt. für Systematik, Ökologie und Geographie der Tiere.

ALEX.: ALEXANDER; BERGR.: BERGROTH; BRUN.: BRUNETTI; COQ.; COQUILLETT; DOL.: DOLESCHALL; EDW.: EDWARDS; END.: ENDERLEIN; KERT.: KERTESZ; LACKS.: LACKSCHEWITZ; LATR.: LATREILLE; MACQ.: MACQUART; MATS.: MATSUMURA; MEIG.: MEIGEN; MEIJ.: DE MEIJERE; O. S.: OSTEN SACKEN; ROND.: RONDANI; SCHIN.: SCHINER; SINT.: SINTENIS; WALK.: WALKER; WESTW.: WESTWOOD; WIED.: WIEDEMANN; WULP: VAN DER WULP; ZETT.: ZETTERSTEDT.

a: antenna; Dist: Distribution; f: figure; h: ♂ hypopygium; k: key to subgenera; L: larva; n: note; No Sg: Sg not mentioned; P: pupa; Sg: subgenus; ssp: subspecies; t: type locality; w: wing or wing venation.

Plate 1, fig. 1, etc. indicates as I:1, etc.

Tribe **HEXATOMINI**

Hexatomini ALEX.: MCAS, 25:890, 920 (1919); MCAS, 38:794, 795, 835–8 (1920) [L; P]; FG, 43, 46–8 (1934); BCSS, 64:297, 365–6 (1942); PIERRE: FF, 8:70, 129 (1924); COE: HIBI, 22, 36–7 (1950).

Limnophilini BRUN.: FBI, 358, 520–1 (1912); ALEX.: MCAS, 25:890, 913 (1919); PIERRE: FF, 8:70, 115 (1924).

Anisomerini BRUN.: FBI, 358, 529 (1912).

Key to Genera & Subgenera

1. Wings of ♀ reduced; venation distorted.··· ····· **Limnophila** (**Prionolabis,** part)
   Fully-winged species in both sexes.····· 2
2. Antennae with usually not more than 12 segments; if 13-segmented, wings with cell M_1 lacking. ·····3
   Antennae with usually 14 segments or more; if 13-segmented, wings with cell M_1 present. ·····5
3. No tuberculate pits; antennae with pedicel elongate; wings with cell *1st* M_2 closed.··· ·····**Nippolimnophila**
   A strong protuberance or tubercle on the vertex.····· (**Hexatoma**) ·····4
4. Wings with two branches of *M* reach the margin; cell *1st* M_2 open; ovipositor with fleshy valves.····· Sg **Hexatoma,** s. str.
   Wings with usually three or four branches of *M* reach the margin; when only two such branches are found, the ovipositor with sclerotized cerci; cell *1st* M_2 closed. ····· Sg **Eriocera**
5. Rostrum elongate, exceeding one-half the length of the entire body. ····· ····· (**Elephantomyia**)·····6
   Rostrum short, or of moderate length only, not exceeding in length the remainder of head.·····7
6. Wings with two branches of *Rs* at origin slightly arcuated in almost the same degree each other; tibial spurs present.····· ····· Sg **Elephantomyia,** s. str.
   Wings with *Rs* being in alignment with the deflection of R_{4+5}; R_{2+3} arising almost perpendicularly from the end of sector; tibial spurs lacking.····· Sg **Elephantomyodes**
7. Two branches of *Rs* reach the wing-margin; tibial spurs lacking.·····**Atarba** (**Atarbodes**)
   Three branches of *Rs* reach the wing-margin. ·····8
8. Apical cells of wing with macrotrichia. ·····9
   Cells of wing without macrotrichia.·····12
9. A supernumerary crossvein in cell *M* of wing. ····· **Limnophila** (**Elaeophila,** part)
   No supernumerary crossvein in cell *M* of wing. ·····10
10. Wings with cell R_3 sessile or subsessile; cell M_1 lacking. ·····**Ulomorpha**
    Wings with cell R_3 petiolate; cell M_1 present, rarely lacking, in the latter case with macrotrichia confined to extreme apical cells of wing. ·····11
11. Small species (wing, less than 5.5 mm.); if larger (over 6 mm.), wings with cell M_1 small, distinctly shorter than its petiole; antennae short in both sexes.····· ·····**Paradelphomyia** (**Oxyrhiza**)
    Larger species (wing, over 6 mm.); wings with cell M_1 deep, almost as long as or longer than its petiole; antennae of ♂ elongate.····· **Limnophila** (**Adelphomyia**)
12. A supernumerary crossvein in cell *C* of wing. ····· **Epiphragma**
    No supernumerary crossvein in cell *C* of wing. ·····13
13. Wings with *m-cu* before, at, or close to fork of *M*; if beyond fork of *M*, cell *1st* M_2 elongate, about one-half longer than the distal section of vein M_{1+2}.·····14
    Wings with *m-cu* beyond fork of *M*, at from one-fourth to one-half the length of the cell *1st* M_2. ·····16
14. Wings with anterior arculus lacking; cell M_1 present. ····· **Dactylolabis**
    Wings with anterior arculus present.·····15
15. Wings with Sc_1 ending opposite or beyond fork of *Rs*; cell M_1 usually lacking; antennae of ♂ elongate, not nodulose.···**Taiwanomyia**
    Wings with Sc_1 ending shortly before fork of *Rs*; cell M_1 present; antennae of ♂ short, or elongate nodulose.····· **Polymera**
16. Wings with anterior arculus lacking.····· ····· (**Austrolimnophila**)·····17
    Wings with anterior arculus present.·····18
17. Antennae of ♂ elongate; wings with R_{2+3+4} subequal to anterior branch of *Rs*.····· ····· Sg **Archilimnophila**
    Antennae of both sexes short; wings with R_{2+3+4} shorter than anterior branch of *Rs*. ····· Sg **Austrolimnophila,** s. str.
18. Wings with *Sc* relatively short, Sc_1 ending before fork of *Rs*.·····**Pilaria**
    Wings with *Sc* longer, Sc_1 ending opposite or beyond fork of *Rs*.·····19
19. Head strongly narrowed and prolonged behind; wings with radial and medial veins beyond cord long and sinuous; vein R_3 extending generally parallel to vein R_4, not diverging markedly at tips; vein *2nd A* strongly

curved to margin.·····**Pseudolimnophila**

Head broad, not conspicuously narrowed behind; wings with radial and medial veins more nearly straight; vein R_3 diverging strongly from vein R_4; cell R_3 conspicuously widened at margin; vein *2nd A* not curved strongly into margin.·····(**Limnophila,** part)·····20

20. Supernumerary crossveins in either cell R_3 or cell M of wing. ·····21

No supernumerary crossveins in any cells of wing. ·····22

21. A supernumerary crossvein in cell R_3 of wing. ····· Sg **Dicranophragma**

A supernumerary crossvein in cell M of wing. ·····Sg **Elaeophila,** part

22. Very large species (wing, over 16 mm.); wings with the branches of M leaving the main stem at a strong angle, cell *1st* M_2 thus being strongly hexagonal. ···Sg **Eutonia**

Smaller species (wing, under 14 mm.); wings with the branches of M not strongly divergent, especially M_{3+4}, cell *1st* M_2 being more nearly rectangular in outline.·····23

23. Wings with *Sc* short, Sc_1 ending about opposite three-fifths to five-sixths the length of *Rs*; cell M_1 lacking.·····Sg **Dendrolimnophila**

Wings with *Sc* longer, Sc_1 ending almost at or beyond fork of *Rs*; cell M_1 usually present.·····24

24. Wings with R_{2+3+4} short, subequal to the basal deflection of R_5; *Rs* elongate, exceeding four times R_{2+3+4}; coloration polished black (*munda* group) or grey (*rufibasis* group), the latter group having the ♂ hypopygium with a series of teeth on margin of outer dististyle, producing a comb-like appearance. ····· Sg **Prionolabis,** part

Wings with R_{2+3+4} longer, usually exceeding the basal deflection of R_5; *Rs* shorter, not exceeding three times R_{2+3+4}; body-coloration never polished black; when grey, the ♂ hypopygium without a comb of spines on the outer dististyle. ·····25

25. Wings with *Rs* short, weakly to more strongly angulated at origin, more rarely arcuated; R_{2+3+4} subequal to or shorter than *m-cu*; antennae short in both sexes.····· ····· Sg **Phylidorea**

Wings with *Rs* longer, more gently arcuated; in species with *Rs* shorter, with antennae of ♂ elongate.·····26

26. Head narrowed behind; wings spotted.····· ····· Sg **Limnophila,** s. str.

Head rounded behind; wings unspotted.····· ····· **nemoralis** group

Genus **PARADELPHOMYIA** Alex., 1936

Paradelphomyia Alex.: PJS, 60:184 [*Adelphomyia*].

Type: *Adelphomyia* (*P.*) *crossospila* Alex.

Subgenus **OXYRHIZA** Meij., 1946

Oxyrhiza Meij.: Ent. Ber., Haar 1em, 12:68 [nom. nov. for *Oxydiscus*].

Type: *Oxydiscus nebulosus* Meij.

Oxydiscus Meij., 1913: TE, 56:350-1; Brun.: RIM, 17:247 (1920); Alex.: PJS, 43:521 (1930); PJS, 66:324 (1938); BCSS, 64:365, 366-7 (1942); Coe: HIBI, 36, 45 (1950) [praeocc. Koken].

Type: *Oxydiscus nebulosus* Meij.

Adelphomyia auct. (nec Bergr., 1891): Kert.: Cat. Dipt., 2:302 (1902); Alex.: MCAS, 25:913, 914 (1919); MCAS, 38:895-6 (1920) [L; P]; FG, 46 (1934); Pierre: FF, 8:113, 114, 143, f. 1(L); 1¹ (P) (1924); End.: TM, 21 (1936); Lacks.: AN-MW, 50:69 (1940).

P. (O.) macracantha Alex., 1957: PJS, 85:357-8, I:3(h); 4(w), t: Kami-Ishikawa, Echigo; Kurokawa, Echigo (♂♀).

Dist: **JAPAN** (Honshu).

P. (O.) nimbicolor Alex., 1950: AESA, 43:427, t: Funakosi, Iwate (♂♀).

Dist: **JAPAN** (Honshu).

P. (O.) nipponensis (Alex., 1925): AM, (9) 15: 77 [*Adelphomyia*], t: Yumoto, Shimotsuke (♀); AESA, 43:427 (1950); PJS, 85:358 (1957) [n].

Dist: **JAPAN** (Honshu).

Genus **AUSTROLIMNOPHILA** Alex., 1920

Austrolimnophila Alex.: AZ, 13 (6): 4-5 [*Limnophila*]; BCSS, 64:366, 372 (1942); Edw.: TSBE, 5:67 (1938); Coe: HIBI, 36, 39, f. 13b (wing-base) (1950).

Type: *Limnophila eutaeniata* Bigot

Subgenus **AUSTROLIMNOPHILA,** s. str.

A. (A.) erecta (Alex., 1934): PJS, 53:281-2, I:11 (w) [*Pseudolimnophila*], t: Lake Chuzenji, Shimotsuke; Konseitoge, Shimotsuke (♀) [comb. nov].

Dist: **JAPAN** (Honshu).

A. (A.) horii (Alex., 1925): AM, (9) 15:391 [*Pseudolimnophila*], t: Gokanosho, Higo (♂♀); PJS, 42:507, 508 [*Pseudolimnophila*] (1930); PJS, 53:281 [*Pseudolimnophila*] (1934) [n]; PJS, 82: 292-3 (1954) [n].

Dist: **JAPAN** (Shikoku; Kyushu).

A. (A.) kirishimensis (Alex., 1924): AESA, 17: 438-9 [*Limnophila*], t: Mt. Kirishima, on boundary between Osumi and Hiuga (♂♀); AM, (9) 15:391 [*Pseudolimnophila*] (1925); PJS, 82:163 [No Sg] (1953).

Dist: **JAPAN** (Shikoku; Kyushu).

A. (A.) mobilis (Alex., 1934): PJS, 53:280-1, I:9 (w); II:31 (h) [*Pseudolimnophila*], t: Sôunkyô

(♂) [comb. nov.].
Dist: **JAPAN** (Hokkaido).

A. (A.) yumotana (ALEX., 1934): PJS, 53:281, I: 10(w); II:32(h) [*Pseudolimnophila*], t: Yumoto, Shimotsuke (♂) [comb. nov.].
Dist: **JAPAN** (Honshu).

Subgenus **ARCHILIMNOPHILA** ALEX., 1934

Archilimnophila ALEX.: FG, 47, 52; BCSS, 64:372 (1942) [as syn. of *Austrolimnophila*]; AESA, 43: 429 (1950).
Type: *Limnophila unica* O. S.

A. (A.) unicoides (ALEX., 1924): PJS, 24:574-5 [*Limnophila*], t: Shimizu, Saghalien; Kamiotoineppu, Hokkaido; Teppetsu, Hokkaido; Akan, Hokkaido (♂♀) [comb. nov.].
Dist: **JAPAN** (Hokkaido); **SAKHALIN.**

Genus **EPIPHRAGMA** O. S., 1859

Epiphragma O. S.: PAP, 1859:238 [*Limnophila*]; MD, 4:47, 193-4 (1869); BEZ, 31:208 (1887); SCHIN.: FA, 2:XXVIII, 550-1 (1864); KERT.: Cat. Dipt., 2:303 (1902); COQ: PUNM, 37:538 (1910); ALEX.: MCAS, 25:913, 914-5 (1919); MCAS, 38: 843-4 (1920) [L; P]; PJS, 49:257-61 (1932) [k]: FG, 46 (1934); BCSS, 64:365, 368 (1942); BRUN.: RIM, 17:255 (1920); PIERRE: FF, 8:115, 116, 143, f. m(L); m¹(P) (1924); END.: TM, 21, f. 36(w) (1936); COE: HIBI, 36, 39 (1950).
Type: *Limnobia fascipennis* SAY (as *pavonina*, sp. nov.).

Subgenus **EPIPHRAGMA,** s. str.

E. (E.) evanescens ALEX., 1940: LSJ, 19:130-1, f. 6(w), t: Tien-mu-shan, Chekiang, China; Wakayama, Honshiu, Japan (♀); TSES, 3:80 (1953).
Dist: **JAPAN** (Honshu; Shikoku); **E. CHINA.**

E. (E.) subfascipennis ALEX., 1920: TAES, 46: 10-1 [No Sg], t: Saitama (♂♀); PJS, 51:370 (1933); TSES, 3:80 (1953); ESAKI: IIJ, 199, f. 387(♂) [No Sg] (1932); IIJ, 2:1522, f. 4365(♂) [No Sg] (1950).
Dist: **JAPAN** (Honshu; Shikoku; Kyushu).

E. (E.) subinsignis ALEX., 1920: TAES, 46:11-2 [No Sg], t: Saitama; Mt. Takao, Musashi (♂); PJS, 24:574 [No Sg] (1924); TSES, 3:81 (1953); ESAKI: IIJ, 199, f. 388(♀) [No Sg] (1932); IIJ, 2:1522, f. 4366(♀) [No Sg] (1950).
Dist: **JAPAN** (Hokkaido; Honshu: Shikoku; Kyushu).

E. (E.) trichomera ALEX., 1954: PJS, 83: 286-7, III:27(w); 28(h), t: Mt. Saragamine, Iyo; Omogo Valley, Iyo (♂♀).
Dist: **JAPAN** (Shikoku).

Genus **POLYMERA** WIED., 1821

Polymera WIED.: Dipt. Exot., 1:40; MACQ.: HNI, 1:72, 112-3 (1834); O. S.: MD, 4:335-6 (1869); MD, Add., xiii (1873); BEZ, 31:215-6 (1887); ALEX.: MCAS, 38:893-4 (1920); PJS, 49:120 (1932); FG, 47 (1934).
Type: *Chironomus hirticornis* FABRICIUS

P. parvicornis ALEX., 1932: PJS, 49:119-20, I:12 (w); III:38(h), t: Kibune, Kyoto (♂).
Dist: **JAPAN** (Honshu).

Genus **TAIWANOMYIA** ALEX., 1923

Taiwanomyia ALEX.: PJS, 22:476-7; PJS, 85:360 (1957).
Type: *Taseocera fragilicornis* RIEDEL
Troglophila BRUN., 1924: RIM, 26:99-100 [*Limnophila*]; ALEX.: PJS, 31:373-5 (1926) [key to spp.]; PJS, 49:120 (1932).
Type: *Limnophila* (*T.*) *cavernicola* BRUN.
Esakiomyia ALEX., 1925; AM, (9)15:73-4.
Type: *Esakiomyia filicornis* ALEX.

T. babaella ALEX., 1957: PJS, 85:358-60, I:5(w), t: Kurokawa, Echigo; Mt. Donden, Sado Island (♂).
Dist: **JAPAN** (Honshu).

T. filicornis (ALEX., 1925): AM, (9) 15:74-5 [*Esakiomyia*], t: Mt. Hakone, Sagami (♂); PJS, 31:374 [*Troglophila*] (1926); PJS, 85:360, I:7(w) (1957).
Dist: **JAPAN** (Honshu).

Genus **DACTYLOLABIS** O. S., 1859

Dactylolabis O. S.: PAP, 1859:240 [*Limnophila*]; MD, 4:198-9 [*Limnophila*] (1869); SCHIN.: FA, 2: XXVIII, 552-4 (1864); KERT.: Cat. Dipt. 2:303 (1902); END.: ZJ, 32:49 (1912) [type as *Limnobia dilatata* LOEW]; TM, 22, f. 38(w) (1936); ALEX., MCAS, 25:918 [*Limnophila*] (1919); MCAS, 38: 852-3 (1920) [L; P]; FG, 47 (1934); BCSS, 64:366, 369 (1942); PIERRE: FF, 8:115, 119, 143, f. n(L); n¹(P) (1924); LACKS.: ANMW, 50:74-6 (1940); COE: HIBI, 36, 38(1950).
Type: *Limnophila* (*D.*) *montana* O. S.

Subgenus **DACTYLOLABIS,** s. str.

D. (D.) diluta ALEX., 1922: IIM, 10:183 [No Sg], t: Gifu (♂); TSES, 3:81 (1953); PJS, 82:293, IV:38(h) (1954).
Dist: **JAPAN** (Honshu; Shikoku).

D. (D.) flavidipennis ALEX., 1922: IIM, 10:184 [No Sg], t: Gifu (♀).
Dist: **JAPAN** (Honshu).

D. (D.) longicauda ALEX., 1922: IIM, 10:184-5 [No Sg], t: Mt. Minomo (♂); PJS, 42:507 [No Sg] (1930); TSES 3:81 (1953).
ssp. **longicauda** ALEX., 1922
Dist: **JAPAN** (Honshu; Shikoku; Kyushu).
ssp. **megastylata** ALEX., 1930: PJS, 42:521 [No Sg] [*longicauda,* ssp.], t: Kosugidani. Yaku-

shima (♂).
Dist: **JAPAN** (Kyushu: Yakushima I.).

Genus **PSEUDOLIMNOPHILA** Alex., 1919

Pseudolimnophila Alex.: MCAS, 25:917, 919 [*Limnophila*]; MCAS, 38:848–50 (1920) [L; P]; PJS, 47:131 (1932); FG, 47 (1934); BCSS, 64:366, 374 (1942); Coe: HIBI, 37, 43, f. 14a (head & anterior parts of thorax) [*Limnophila*] (1950).
Type: *Limnophila luteipennis* O. S.

Subgenus **PSEUDOLIMNOPHILA,** s. str.

P. (P.) inconcussa (Alex., 1913): CE, 45:313–4, IV:2(w); X:12(h) [*Limnophila*], t: Tokyo (♂♀); PUNM, 58:435, XXIII:9(w) [*Limnophila*] (1920); PJS, 24:574 [*Limnophila*] (1924); PJS, 31:380 [No Sg] (1926); NEC, 4:75 [No Sg] (1937); PJS, 82:164 [No Sg] (1953); Riedel: Arch. Naturg., 82A:114 [*Limnophila*] (1917); Esaki: IIJ, 200, f. 389(♀) [No Sg] (1932); IIJ, 2:1522, f. 4367(♀) [No Sg] (1950).
Dist: **JAPAN** (Hokkaido; Honshu; Shikoku; Kyushu); **FORMOSA; CHINA.**

P. (P.) telephallus Alex., 1957: PJS, 85:360–2, I: 9(w); 10(h) [No Sg], t: Kurokawa, Echigo; Tamagawa, Ugo; Lake Tazawa, Ugo (♂♀).
Dist: **JAPAN** (Honshu).

Genus **LIMNOPHILA** Macq., 1834

Limnophila Macq.: HNI, 1:71, 95; Westw.: Intr., 2, Synops., 128 (1840); Rond.: PDI, 1:183 [*Limnopmila*!] (1856) [type as *Limnobia punctata* Meig.]; Schin.: FA, 2:XXVIII, 554–8 (1864); O. S.: MD, 4:47, 196–204 (1869); BEZ, 31:209–10 (1887); Skuse: PLSN, (2)4:838–40 (1890); Kert.: Cat. Dipt., 2:307 (1902); Brun.: RIM, 6:306 (1911); FBI, 521–3 (1912); RIM, 15: 323–4 (1918); RIM, 17:252 (1920); Alex.: CE, 45:313 (1913) [k; key to spp.]; MCAS, 25:913, 915–20 (1919) [k]; MCAS, 38:857, 858–60, 868–9 (1920) [L; P]; PJS, 24:574 (1924); PJS, 49:267–9 (1932) [k]; FG, 46, 47–8, 52 (1934) [k]; BCSS, 64:366, 378–9, 405 (1942); Pierre: FF, 8:115, 121–4, 143, f. o, o^1(L): o^2(P) (1924); End.: TM, 22 (1936); Lacks.: ANMW, 50:83–6 (1940); Coe: HIBI, 36–7, 39–45, f. 14b (head & anterior parts of thorax) (1950) [k].
Type: *Limnobia pictipennis* Meig.

Limnomya Rond., 1861: PDI, 4:11 [nom. nov. for *Limnophila*]; O. S.: BEZ, 31:232 [*Limnomyia*!] (1887).
Type: *Limnobia punctata* Meig.

Poecilostola Schin., 1863: WEM, 7:222; FA, 2:XXVIII, 551–2 (1864); O. S.: MD, 4:200 (1869); Kert.: Cat. Dipt., 2:306 (1902); Alex.: CE, 45: 313 [*Limnophila*] (1913); Brun.: RIM, 17:256 (1920); Pierre: FF, 8:115, 119 (1924).
Type: *Limnobia pictipennis* Meig.

Subgenus **ADELPHOMYIA** Bergr., 1891

Adelphomyia Bergr.: Mitt. Naturf. Ges. Bern, 1890: 134; Alex.: PJS, 66:324 [*Limnophila*] (1938); PJS, 71:191 [*Limnophila*] (1940).
Type: *Limnobia punctum* Meig. (as *helvetica*, sp. nov.).

Tricholimnophila Alex., 1928: PJS, 35:476–7 [*Limnophila*].
Type: *Limnophila* (*Lasiomastix*) *pilifer* Alex.

L. (A.) acicularis Alex., 1954: PJS, 82:293–5, V: 42(w); 47(h), t: Mt. Tsurugi, Minokosi to Nagoro, Awa; Nisigawa to Kokusen, near Yanase, Tosa; Imanoyama, Tosa; Minokosi, Mt. Tsurugi, Awa (♂♀).
Dist: **JAPAN** (Shikoku).

L. (A.) biacus Alex., 1954: PJS, 82:295–6, V: 43(w); 48(h), t: Mt. Ishizuchi, Iyo; Omogokei, Iyo (♂♀); TSES, 3:81 (1953) [nom. nud.].
Dist: **JAPAN** (Shikoku).

L. (A.) brevirama Alex., 1925: AM, (9)15:71–2 [Sg *Lasiomastix*] [*breviramus*!], t. Yumoto, Shimotsuke (♂); PJS, 35:476 [Sg *Tricholimnophila*] [*breviramus*!] (1928); TSES, 3:81 (1953).
Dist: **JAPAN** (Honshu; Shikoku; Kyushu).

L. (A.) caesiella Alex., 1929: PJS, 40:538 [Sg *Tricholimnophila*], t: Hirao Hill, near Fukuoka; Fukuoka (♂); TSES, 3:81 (1953).
Dist: **JAPAN** (Shikoku; Kyushu).

L. (A.) flavella Alex., 1920: TAES, 46:12–3 [Sg *Lasiomastix*], t: Tokio (♂♀); PJS. 35:476 [Sg *Tricholimnophila*] (1928).
Dist: **JAPAN** (Honshu).

L. (A.) macrotrichiata Alex., 1923, AESA, 16: 65–6 [Sg *Lasiomastix*], t: Teshio (♂): PJS, 35:477 [Sg *Tricholimnophila*] (1928); PJS, 71:49, I:7(w) (1940).
Dist: **JAPAN** (Hokkaido); **N. KOREA.**

L. (A.) pilifer Alex., 1919: AESA, 12:339–40 [Sg *Lasiomastix*], t: Meguro, Tokio (♂♀); PJS, 35: 476 [Sg *Tricholimnophila*] (1928); PJS, 53:286 [Sg *Tricholimnophila*] (1934) [n].
Dist: **JAPAN** (Honshu).

L. (A.) prionolaboides Alex., 1934: PJS, 53:285–7, I:15(w); III:36(h) [Sg *Tricholimnophila*], t: Yumoto, Shimotsuke (♂♀).
Dist: **JAPAN** (Honshu).

L. (A.) saitamae Alex., 1920: TAES, 46:13 [Sg *Lasiomastix*] [*flavella*, ssp.], t: Saitama (♂); PJS, 35:476 [Sg *Tricholimnophila*] [*flavella*, ssp.] (1928); PJS, 42:507 [Sg *Tricholimnophila*] (1930).
Dist: **JAPAN** (Honshu; Kyushu).

L. (A.) satsumicola Alex., 1930: PJS, 42:524 [Sg *Tricholimnophila*], t: Shiroyama Hill, city of Kagoshima (♂♀).
Dist: **JAPAN** (Kyushu).

Subgenus **EUTONIA** Wulp, 1874

Eutonia Wulp: TE, 17:147; Kert.: Cat. Dipt., 2: 307 (1902); Alex.: JNES, 26:67 [*Limnophila*] (1918); MCAS, 25:917 [*Limnophila*] (1919); FG, 48 [*Limnophila*] (1934); BCSS, 64:378, 390 [*Limnophila*] (1942); Pierre: FF, 8:115, 118 (1924); End.: TM, 22 (1936).
Type: *Limonia barbipes* Meig.

Gagamba Mats., 1916: TIJA, 2:472–3.
Type: *Limnobia Satsuma* Westw. (as *Takei*, sp. nov.).

L. (E.) satsuma (Westw., 1876): TES, 1876:504–5, III:5a(a); 5b(w) [*Limnobia Satsuma*], t: Japonia (♂); Kert.: Cat. Dipt., 2:285 [*Limnobia Satsuma*] (1902); Alex.: CE, 45:313, 314–6, III: 4(w); X:11(h) [Sg *Poecilostola*] (1913) [♂ redescription]; JNES, 26:67 (1918); PJS, 82:64 (1953); Esaki: IIJ, 201, f. 391(♂) [No Sg] (1932); IIJ, 2:1523, f. 4369(♂) [No Sg] (1950).

Takei Mats., 1916: TIJA, 2:471–2, XXV:12(♂) [*Gagamba*], t: Saitama; Kyoto; Osaka; 6000 Ill. Ins. Jap.-Emp., 394, f. (♂) [*Gagamba*] (1931); Ill. Com. Ins. Jap., 6:38 (in Jap.) & 55 (in Eng.), X:8(♂) [*Gagamba*] (1932).
Dist: **JAPAN** (Honshu; Shikoku; Kyushu).

Subgenus **PRIONOLABIS** O. S., 1859

Prionolabis O. S.: PAP, 1859:239 [*Limnophila*]; MD, 4:197–8 [*Limnophila*] (1869); Alex., MCAS, 25:916, 919 [*Limnophila*] (1919); FG, 48 [*Limnophila*] (1934); BCSS, 64:379, 391 [*Limnophila*] (1942).
Type: *Limnophila* (*P.*) *rufibasis* O. S.

L. (P.) acutistyla Alex., 1925: AM, (9)15:389 [*acutistylus*!], t: Mt. Wakasugi, Chikuzen (♂♀); PJS, 82:296, IV:39(h) [*acutistylus*!] (1954).
Dist: **JAPAN** (Shikoku; Kyushu).

L. (P.) atrofemorata Alex., 1954: TSES, 4:30 [nom. nov. for *nigrofemorata*]; PJS, 83:287–8 (1954) [♀].

nigrofemorata Alex., 1938: PJS, 66:117–8, I:14 (w); III:39 (h), t: Mt. Nanshô, Iwate (♂) [praeocc. Alex., 1927].
Dist: **JAPAN** (Honshu; Shikoku).

L. (P.) auribasis Alex., 1918: AESA, 11:446, t: Osaka (♀); EM, 3:126 (1919); PJS, 82:164 (1953); Esaki: IIJ, 202, f. 393 (♂) [No Sg] (1932); IIJ, 2:1524, f. 4371 (♂) [No Sg] (1950).
Dist: **JAPAN** (Honshu; Shikoku).

L. (P.) extensa Alex., 1958: TSES, 6:6–7, t: Misaka-toge, Iyo (♂♀).
Dist: **JAPAN** (Shikoku).

L. (P.) imanishii Alex., 1932: PJS, 49:122–3, III: 40 (♀ a) [No Sg], t: Bogaya, Toyama, Japanese Alps (♀); PJS, 53:284 (1934) [n].
Dist: **JAPAN** (Honshu).

L. (P.) inermis Alex., 1934: PJS, 53:285, I:14 (w); III:35(h), t: Lake Chuzenji, Shimotsuke (♂♀).
Dist: **JAPAN** (Honshu).

L. (P.) isis Alex., 1958: TSES, 6:4–5, f. 2 (w); 3 (h), t: Mt. Hukumi, Iyo (♂).
Dist: **JAPAN** (Shikoku).

L. (P.) iyoensis Alex., 1954: PJS, 83:288–9, III: 29 (w); 30 (h), t: Kurotaki, Iyo; Sugitate, Iyo (♂♀).
Dist: **JAPAN** (Shikoku).

L. (P.) kunumiana Alex., MS: PJS, 83:289 (1954) [nom. nud.]; TSES, 6:7 (1958) [nom. nud.].
Dist: **JAPAN** (Kyushu).

L. (P.) liponeura Alex., 1930: PJS, 42:523–4, II: 28 (h), t: Mt. Kirishima (♂♀).
Dist: **JAPAN** (Kyushu).

L. (P.) lipophleps Alex., 1930: PJS, 42:522–3, I: 14 (w); II:27 (h), t: Kosugidani, Yakushima (♂♀).
Dist: **JAPAN** (Kyushu: Yakushima I.).

L. (P.) luteibasalis Alex., 1934: PJS, 53:283–4, I:13 (w); III:34 (h), t: Konseitoge, Shimotsuke (♂♀).
Dist: **JAPAN** (Honshu).

L. (P.) majorina Alex., 1958: TSES, 6:5–6, t: Misaka-toge, Iyo (♂).
Dist: **JAPAN** (Shikoku).

L. (P.) neomunda Alex., 1924: AESA, 17:437, t: Sapporo, Ishikari (♂♀).
Dist: **JAPAN** (Hokkaido).

L. (P.) nigrilunae Tokunaga, 1935: Annot. zool. Jap., 15:196–8, XIV:1 (♀) [No Sg], t: Kamikochi, Nagano, Japanese Alps (♀); Alex.: PJS, 71:49 (1940).
Dist: **JAPAN** (Honshu).

L. (P.) odai Alex., 1933: PJS, 51:370, 400–1, I:20 (w); IV:50 (h), t: Mt. Kiyozumi, Boso Peninsula, Kazusa (♂♀); PJS, 82:165 (1953) [n].
Dist: **JAPAN** (Honshu; Shikoku).

L. (P.) recurvans Alex., 1953: PJS, 82:64–5, II: 18 (w); 23 (h), t: Nisigawa to Yanase, Tosa; Iwai, near Imanoyama, Tosa (♂♀).
Dist: **JAPAN** (Shikoku).

L. (P.) rufipennis Alex., 1919: AESA, 12:341, t: Chichibu, Saitama (♂).
Dist: **JAPAN** (Honshu).

L. (P.) shikokuana Alex., 1953: PJS, 82:65–6, II: 19 (w); 24 (h), t: Mt. Tsurugi, Awa; Mt. Tsurugi, Minokosi to Nagoro, Awa (♂♀).

Dist: **JAPAN** (Shikoku).

L. (P.) sôunkyana Alex., 1934: PJS, 53:282-3, I: 12 (w); II:33 (h), t: Sôunkyô (♂♀).
Dist: **JAPAN** (Hokkaido).

L. (P.) submunda Alex., 1918: AESA, 11:446, t: Kioto (♂♀); EM, 3:125-6 (1919); PJS, 42: 507. 508 (1930); PJS, 51:401 (1933) [n]; TSES, 3:81 (1953).
Dist: **JAPAN** (Honshu; Shikoku; Kyushu).

L. (P.) uncinata Alex., 1954: PJS, 82:295-7, IV: 40 (h); V:41 (w), t: Omogokei (♂); TSES 3:81 (1953) [nom. nud.].
Dist: **JAPAN** (Shikoku).

L. (P.) yamamotana Alex., 1958: PJS, 66:118-9, I:15 (w); III:40 (h), t: Matsuo, Iwate (♂♀).
Dist: **JAPAN** (Honshu).

Subgenus **DENDROLIMNOPHILA** Alex., 1949

Dendrolimnophila Alex.: Amer. Midl. Nat., 42:314 [*Limnophila*]; PJS, 82:67 [*Limnophila*] (1953).
Type: *Shannonomyia albomanicata* Alex.

L. (D.) shikokuensis Alex., 1953: PJS, 82:66-7, II:20 (w); 25 (h), t: Nisigawa to Kokusen, near Yanase, Tosa (♂♀).
Dist: **JAPAN** (Shikoku).

Subgenus **PHYLIDOREA** Bigot, 1854

Phylidorea Bigot: ASEF, (3)2:456; Coq.: PUNM, 37:590 (1910); Alex.: MCAS, 25:918, 919 [*Limnophila*] (1919); MCAS, 38:857, 858, 866-7 [*Limnophila*] (1920) [L; P]; FG, 48 [*Limnophila*] (1934); BCSS, 64:379, 394-6 [*Limnophila*] (1942); Coe: HIBI, 36, 39-40 [*Limnophila*] (1950).
Type: *Limnobia ferruginea* Meig.

L. (P.) hokkaidensis Alex., 1947: AESA, 40:357-8, t: Sapporo (♀).
Dist: **JAPAN** (Hokkaido).

L. (P.) kuwayamai Alex., 1924: AESA, 17:440 [No Sg], t: Sapporo, Ishikari (♂).
Dist: **JAPAN** (Hokkaido).

L. (P.) melanommata Alex., 1921: AESA, 14:120, t: Koiwai Farm, near Morioka (♀).
Dist: **JAPAN** (Honshu).

L. (P.) mundella Alex., 1931: PJS, 44:357, I:13 (w) [No Sg], t: Norikuradake, Japanese Alps, Shinano (♀); PJS, 83:289 (1954).
Dist: **JAPAN** (Honshu; Shikoku).

L. (P.) sapporensis Alex., 1921: IIM, 9:181-2, t: Sapporo (♂); PJS, 24:577 (1924).
Dist: **JAPAN** (Hokkaido); **SAKHALIN**.

L. (P.) yamamotoi Alex., 1936: PJS, 60:186, I:12 (w), t: Iwate-gun, Iwate (♀).
Dist: **JAPAN** (Honshu).

Subgenus **LIMNOPHILA**, s. str.

L. (L.) aino Alex., 1929: PJS, 40:340-1, III:37 (h) [No Sg], t: Jozankei (♂); PJS, 71:187 (1940).
Dist: **JAPAN** (Hokkaido).

L. (L.) dicranophragmoides Alex., 1924: IIM, 12:157-8 [No Sg], t: Kunjan-gun, Okinawa; Shuri, Okinawa (sex ?); PJS, 71:187 (1940).
Dist: **JAPAN** (Loochoo Is.: Okinawa I.).

L. (L.) japonica Alex., 1913: CE, 45:313, 316-7, III:2 (w); X:10 (h) [Sg *Poecilostola*], t: Tokyo (♂♀); PJS, 24:574 (1924) [n]; PJS, 82:165 (1953); Esaki: IIJ, 200, f. 390 (♂) [No Sg] (1932); IIJ, 2:1523, f. 4368 (♂) [No Sg] (1950).
Dist: **JAPAN** (Hokkaido; Honshu; Shikoku; Kyushu); **SAKHALIN**.

L. (L.) varicornis Coq., 1898: PUNM, 21:304 [No Sg], t: Japan (♂); Kert.: Cat. Dipt., 2:312 [No Sg] [*variicornis*!] (1902); Alex.: CE, 45:313, 317 [Sg *Poecilostola*] (1913) [n]; PJS, 52:339 (1933); NEC, 4:75 (1937); Wu: Cat. Ins. Sin., 5:47 [*variicornis*!] (1940).
Dist: **JAPAN**; **CHINA**.

Subgenus **DICRANOPHRAGMA** O. S., 1859

Dicranophragma O. S.: PAP, 1859:240 [*Limnophila*]; MD, 4:199 [*Limnophila*] (1869); Brun.: FBI, 521, 524 (1912); RIM, 17:255 (1920); Alex.: MCAS, 25:916 [*Limnophila*] (1919); MCAS, 38: 857, 858, 861 [*Limnophila*] (1920) [L; P]; PJS, 49:268-9 [*Limnophila*] (1932); FG, 48 [*Limnophila*] (1934); BCSS, 64:378, 381-2 [*Limnophila*] (1942).
Type: *Limnophila* (*D.*) *fuscovaria* O. S.

L. (D.) formosa Alex., 1920: AESA, 13:258-9, t: Funkiko, Formosa (♂); PJS, 82:33 [Sg *Elaeophila*] (1953); PJS, 83:291 (1954); Esaki: IIJ, 201, f. 392 (♂) [No Sg] (1932); IIJ, 2:1523, f. 4370 (♂) [No Sg] (1950).
Dist: **JAPAN** (Honshu); **FORMOSA**.

L. (D.) melaleuca Alex., 1933: PJS, 52:143-4, I: 8 (w), t: Wakasugiyama, Chikuzen (♂).
ssp. **melaleuca** Alex., 1933
Dist: **JAPAN** (Kyushu).

L. (D.) microspila Alex., 1953: PJS, 82:165-7, III:18 (w); 19 (h), t: Mt. Ishizuchi, Koguti, Iyo; Mt. Tsurugi, Minokosi to Nagoro, Awa; Mt. Tsurugi, Sugeoi, Awa (♂♀).
Dist: **JAPAN** (Shikoku).

L. (D.) perlata Alex., 1954: PJS, 83:289-91, III: 32 (w), t: Mt. Saragamine, Iyo (♂).
Dist: **JAPAN** (Shikoku).

L. (D.) upsilon Alex., 1925: AM, (9) 15:72, t: Hinoëmata, Iwashiro (♀); PJS, 82:167 (1953) [n].
Dist: **JAPAN** (Honshu).

Subgenus **ELAEOPHILA** Rond., 1856

Elaeophila Rond.: PDI, 1:182; O. S.: BEZ, 31:232

(1887); Alex., PJS, 49:268 [*Limnophila*] (1932); FG, 48 [*Limnophila*] (1934); BCSS, 64:378, 384-5 [*Limnophila*] (1942); PJS, 85:363 [*Limnophila*] (1957); Coe: HIBI, 36, 40-2 [*Limnophila*] (1950).
Type: *Limonia maculata* Meig. (as *Limnobia marmorata* Hoffmannsegg).

Ephelia Schin., 1863: WEM, 7:222; FA, 2:XXVIII, 549-50 (1864); O. S.: MD, 4:199-200 (1869); Kert.: Cat. Dipt., 2:305 (1902); Brun.: FBI, 521, 525 (1912); RIM, 17:256 (1920); Pierre: FF, 8:115, 117-8 (1924); End.: TM, 22, f. 37 (w) (1936); Lacks.: ANMW, 50:72-3 (1940).
Type: *Limonia maculata* Meig. (as *Limnobia marmorata* Meig.).

Trichephelia Alex., 1934: FG, 46 [*Limnophila*]; BBES, 33:73 [*Limnophila*] (1938).
Type: *Limnophila* (*T.*) *seticellula* Alex.

L. (E.) amamiana Alex., 1955: AM, (12) 8:671-2, t: Shinmura, Amami Oshima (♂).
Dist: **JAPAN** (Loochoo Is.: Amami-Oshima I.).

L. (E.) dietziana Alex., 1924: AESA, 17:437-8 [Sg *Ephelia*], t: Mt. Hakone, Sagami; Tamagawa, Musashi (♂); PJS, 31:373, II:12 (h) [Sg *Ephelia*] (1926); PJS, 42:507 [Sg *Ephelia*] (1930); PJS, 59:247 (1936) [n]; PJS, 82:167 (1953).
Dist: **JAPAN** (Honshu; Shikoku; Kyushu).

L. (E.) kintaro Alex., 1957: PJS, 85:362-3, I:11 (h); 12 (w), t: Kurokawa, Echigo (♂♀).
Dist: **JAPAN** (Honshu).

L. (E.) lilliputina Alex., 1936: PJS, 59:246 7, I: 18 (w); II:32 (h), t: Kibune, Kyoto (♂).
Dist: **JAPAN** (Honshu).

L. (E.) subaprilina Alex., 1919: AESA 12:340-1 [Sg *Ephelia*], t: Meguro, Tokio; Tokio (♂♀); PJS, 31:373, II:14 (h) [Sg *Ephelia*] (1926); NEC, 4:76-7 (1937) [n]; PJS, 67:158-9 (1938) [n]; PJS, 82:167 (1953).
ssp. **subaprilina** Alex., 1919
Dist: **JAPAN** (Honshu; Shikoku); **N. KOREA**.
ssp. **yezoensis** Alex., 1925: AM, (9) 15:72 [Sg *Ephelia*] [*subaprilina*, ssp.], t: Jozankei, Ishikari (♀); PJS, 71:48 [*subaprilina*, ssp.] (1940) [n].
Dist: **JAPAN** (Hokkaido); **N. KOREA**.

L. (E.) ussuriana Alex., 1933: PJS, 52:142-3, I: 7 (w); II:31 (h) [Sg *Idioptera*], t: Tigrowaja, Suchan district, Ussuri (♂♀); PJS, 67:158 [Sg *Idioptera*] (1938).
Dist: **E. SIBERIA**; **N. KOREA.**
ssp. **iwatensis** Alex., 1936: PJS, 60:187 [Sg *Idioptera*] [*ussuriana*, ssp.], t: Iwate-gun, Iwate (♂♀); PJS, 85:363 [*ussuriana*, ssp.] (1957).
Dist: **JAPAN** (Honshu).

Subgenus **Incertae sedis** (**nemoralis** group)

L. subnemoralis Alex., 1925: AM, (9) 15:73, t: Yumoto, Shimotsuke (♂); PJS, 42:508 [var.] (1930); TSES, 3:81 (1953).
Dist: **JAPAN** (Honshu; Shikoku; Kyushu).

L. transitoria Alex., 1941: PJS, 76:56-7, I:18 (w); IV:42 (h), t: Kamikochi (♂).
Dist: **JAPAN** (Honshu).

Genus **NIPPOLIMNOPHILA** Alex., 1930

Nippolimnophila Alex.: PJS, 42:70-1.
Type: *Nippolimnophila kiusiuensis* Alex.

N. kiusiuensis Alex., 1930: PJS, 42:71-2, I:9 (w); II:29 (a); 30 (h), t: Mt. Kirishima (♂).
Dist: **JAPAN** (Kyushu).

N. omogiana Alex., 1954: PJS, 83:291-2, III:31 (w); IV:38 (h), t: Omogo Valley, Iyo (♂).
Dist: **JAPAN** (Shikoku).

N. perproducta Alex., 1957: PJS, 85:363-4, II:13 (w); 14 (h), t: Kurokawa, Echigo (♂).
Dist: **JAPAN** (Honshu).

N. yakushimensis Alex., 1930: PJS, 42:72, I:10 (w), t: Kosugidani, Yakushima (♂).
Dist: **JAPAN** (Kyushu: Yakushima I.).

Genus **PILARIA** Sint., 1888

Pilaria Sint.: Sitzber. Nat.-Ges. Dorpat, 8:398; Coq.: PUNM, 37:591 (1910); Alex., MCAS, 38: 857, 858, 872-3 (1920) [L; P]; PJS, 49:270-1 (1932) [k]; FG, 47 (1934); BCSS, 64:366, 410-1 (1942); Coe: HIBI, 36-7, 43-5, f. 13a (wing-base); 14c (head & anterior parts of thorax) [*Limnophila*] (1950).
Type: *Limnobia pilicornis* Zett.

Eulimnophila Alex., 1919: MCAS, 25:917 [*Limnophila*].
Type: *Limnobia tenuipes* Say [by Alex.].

P. dorsalis Alex., 1924: PJS, 24:577-8, t: Konuma, Saghalien; Sapporo, Hokkaido (♀).
Dist: **JAPAN** (Hokkaido); **SAKHALIN**.

P. tokionis (Alex., 1920): TAES, 46:13 [*Limnophila* (*Eulimnophila*)], t: Tokio (♂♀).
ssp. **tokionis** (Alex., 1920)
Dist: **JAPAN** (Honshu).
ssp. **melanota** Alex., 1922: IIM, 10:185, t: Gifu (♂); PJS, 82:167 [*tokionis*, ssp.] (1953) [n].
Dist: **JAPAN** (Honshu; Shikoku).

Genus **ULOMORPHA** O. S., 1869

Ulomorpha O. S.: MD, 4:47, 232-3; Alex.: MCAS, 25:913-4 (1919); MCAS, 38: 857, 858, 869 (1920) [L; P]; FG, 46 (1934); BCSS, 64:365, 414 (1942).
Type: *Limnophila pilosella* O. S.

U. nigricolor Alex., 1925: AM, (9) 15:75-6, t: Lake Ozenuma, on boundary between Iwashiro and Kotsuke (♂); PJS, 67:159 [var.] (1938) [n]; PJS, 82:68 (1953) [n].

Dist: **JAPAN** (Honshu; Shikoku; Kyushu); **N. KOREA**.

U. polytricha Alex., 1930: PJS, 42:72 3, I:11(w), t: Kosugidani, Yakushima (♂).
Dist: **JAPAN** (Kyushu: Yakushima I.).

Genus **HEXATOMA** Latr., 1809

Hexatoma Latr.: Gen. Crust. et Ins., 4:260; Meig.: SB, 1:209 [165] (1818); Alex.: MCAS, 25:920 1 (1919); MCAS, 38:877-8 (1920) [L; P]; PJS, 52: 147-8 (1933) [k]; FG, 46 (1934) [k]; BCSS, 64: 365, 415-6 (1942) [k]; Pierre: FF, 8:129, 130, 143, f. p(L); p¹(P) (1924); End.: TM, 22, f. 41 (w) (1936); Lacks.: ANMW, 50:98-102 (1940); Coe: HIBI, 36, 37 (1950).
Type: *Hexatoma nigra* Latr.

Nematocera Meig., 1818: SB, 1:209 [XXIII, 164-5], VII:1 (♂); 2 (a); 3 (head); 4 (w); Rond.: PDI, 1:184 (1856).
Type: *Nematocera bicolor* Meig.

Anisomera Wied., 1818: in Meig., SB, 1:210 [XXIII, 165-6], VII:5 (♂); 6-7 (a); 8 (w); Meig.: SB, 6:291 (1830); Macq.: HNI, 1:72, 117 (1834); Rond.: PDI, 1:184 (1856) [type as *A. nigra* Meig.]; Schin.: FA, 2:XXVII, 532-4 (1864); O. S.: MD, 4:48, 239-43 (1869); BEZ, 31:219 (1887); Kert.: Cat. Dipt., 2:314 (1902).
Type: *Anisomera obscura* Wied.

Peronecera Curtis, 1836: Brit. Ent., 589; Schin.: FA, 2:532 [*Perenocera*!] (1864); O. S.: MD, 4:242 (1869); End: TM, 22, f. 42(a) (1936).
Type: *Peronecera fuscipennis* Curtis

Trimacromera End., 1936: TM, 23, f. 43(a).
Type: *Nematocera nubeculosa* Burmeister

Subgenus **HEXATOMA,** s. str.

H. (H.) japonica Alex., 1922: IIM, 10:185-6 [No Sg], t: Gifu (♂♀); NEC, 4:78 (1937) [n]; TSES, 3:82 (1953).
Dist: **JAPAN** (Honshu; Shikoku).

H. (H.) perproducta Alex., 1958: TSES, 6:7 8, f. 4 (w), t: Iwazeki, near Matsuyama, Iyo (♂♀).
Dist: **JAPAN** (Shikoku).

Subgenus **ERIOCERA** Macq., 1838

Eriocera Macq.: Dipt. Exot., 1(1):74; O. S.: MD, 4:48, 244-52 (1869); BEZ, 31:220-1 (1887); Kert.: Cat. Dipt., 2:316 (1902); End.: ZJ, 32:37 8 (1912) [type as *E. macquarti* End.]; Brun.: 530-3 (1912); RIM, 15:334-5 (1918); RIM, 17:258 (1920); Alex., JNES, 26:67 (1918); MCAS, 25:920, 921-3 (1919); MCAS, 38:877, 881-3 (1920) [L; P]; PJS, 52:147-8 [*Hexatoma*] (1933); FG, 46 [*Hexatoma*] (1934); BCSS, 64:415, 416-7 [*Hexatoma*] (1942); Edw.: AM, (9) 8:67 99, 1 pl., 2 text-figs. (1921) [key to Old World spp.]; Lacks.: ANMW, 50:97 (1940).
Type: *Hexatoma* (*E.*) *wiedemanni* Alex. (as *Limnobia nigra* Wied.).

Caloptera Guérin, 1830: Voy. d. l. Coquille, Zool., Ins., XX:2; Coq.: PUNM, 37:517 (1910).
Type: *Caloptera fasciata* Guérin

Evanioptera Guérin, 1830: ibid., 2(2):287 [nom. nov. for *Caloptera*]; O. S.: MD, 4:249 (1869).
Type: *Caloptera fasciata* Guérin

Pterocosmus Walk., 1848: List Dipt. Brit. Mus., 1: 78; O. S.: MD, 4:249 (1869); Coq.: PUNM, 37: 597 (1910); End.: ZJ, 32:37 (1912) [type as *P. velutinus* Walk.=*Caloptera nepalensis* Westw.].
Type: *Pterocosmus hilpa* Walk.

Allarithmia Loew, 1850: Bernstein & Bernstein-fauna, 38; O. S.: MD, 4:251 (1869).
Type: *Allarithmia palpata* Loew

Oligomera Dol., 1857: Nat. Tijd. Ned. Ind., 14:387; O. S.: MD, 4:249 (1869).
Type: *Oligomera javensis* Dol.

Arrhenica O. S., 1859: PAP, 1859:242; MD, 4:247, 250, 252 [*Eriocera*] (1869); Coq.: PUNM, 37:510 (1910); End.: ZJ, 32:49 (1912).
Type: *Arrheica spinosa* O. S.

Physecrania Bigot, 1859: ASEF, (3) 7:123; O. S.: MD, 4:249 (1869); End.: ZJ, 32:32 (1912).
Type: *Hexatoma* (*E.*) *madagascariensis* Alex. (as *obscura*, sp. nov.).

Penthoptera Schin., 1863: WEM, 7:220; FA, 2: XXVII, 534-5 (1864); O. S.: MD, 4:48, 256-7 (1869); Kert.: Cat. Dipt., 2:316 (1902); Alex.: MCAS, 25:920, 921 (1919); MCAS, 38:877, 891 (1920) [L; P]; FG, 46 [*Hexatoma*] (1934); Pierre: FF, 8:129. 131, 143, f. r(L) (1924); End.: TM, 22, f. 39 (w) (1936).
Type: *Tipula chirothecata* Scopoli

Androclosma End., 1912: ZJ, 32:34-5.
Type: *Megistocera verticalis* Wied.

Globericera Mats., 1916: TIJA, 2:471.
Type: *Globericera moriokana* Mats.

Cerozelia End., 1936: TM, 22, f. 40(w).
Type: *Tipula cimicoides* Scopoli

H. (E.) alboguttata (Mats., 1916): TIJA, 2:468-9, XXV:10 (♀) [*Eriocera*], t: Atami; Iyo; Kumamoto; 6000 Ill. Ins. Jap.-Emp., 393, f. (♀) [*Eriocera*] (1931); Alex.: AZ, 30B(6):3 (1938) [n]; PJS, 82:68 (1953).

hilpa (Edw., 1921): AM, (9) 8:76, part. [*Eriocera*]; Esaki: IIJ, 2:1524, f. 4373 (♂)[*Eriocera*] (1950) [nec Walk., 1848].
Dist: **JAPAN** (Honshu; Shikoku; Kyushu).

H. (E.) cerberus Alex., 1953: PJS, 82:167-8, III: 20 (w), t: Omogokti, Iyo (♂).

Dist: **JAPAN** (Shikoku).

H. (E.) fulvibasis (Alex., 1923): AESA, 16:67–8 [*Eriocera*], t: Teshio (♂).
Dist: **JAPAN** (Hokkaido).

H. (E.) geminata (Alex., 1923): AESA, 16:67 [*Eriocera*], t: Island of Oshima, Tokyo (♂).
Dist: **JAPAN** (Honshu: Izu-Oshima I.).

H. (E.) gifuensis Alex., 1933: PJS, 52:153–5, I: 15 (w); II:33 (h), t: Gifu, Mino (♂♀); PJS, 82:168–9 (1953) [n].
Dist: **JAPAN** (Honshu; Shikoku).

H. (E.) imperator Alex., 1953: PJS, 82:169–70, III:21 (w), t: Odamiyama. Iyo; Omogokei, Iyo (♂).
Dist: **JAPAN** (Shikoku).

H. (E.) iriomotensis Alex., 1935: PJS, 57:213–5, I:14 (w), t: Iriomote Island (♂♀).
Dist: **JAPAN** (Loochoo Is.: Iriomote I.).

H. (E.) ishigakiensis Alex., 1935: PJS, 57:212 3, I:13 (w), t: Ishigaki Island (♀).
Dist: **JAPAN** (Loochoo Is.: Ishigaki I.).

H. (E.) issikii (Alex., 1928): PJS, 36:471–2, I:11 (w) [*Eriocera*], t: Zyogi, near Sendai, Miyagi (♂); PJS, 49:123 [*Eriocera*] (1932) [n].
Dist: **JAPAN** (Honshu).

H. (E.) jozana (Alex., 1924): PJS, 24:578 9 [*Eriocera*], t: Jozankei (♂); Esaki: IIJ, 203 [*Eriocera*] (1932); IIJ, 2:1525 [*Eriocera*] (1950).
Dist: **JAPAN** (Hokkaido).

H. (E.) kamiyai (Alex., 1932): PJS, 49:125–6, I: 16 (w) [*Eriocera*], t: Kamikochi, Shinano, Japanese Alps (♂); PJS, 52:161, II:35 (h) (1933).
Dist: **JAPAN** (Honshu).

H. (E.) kariyai Alex., 1933: PJS, 52:160 1, I:21 (w); II:34 (h), t: Gifu, Mino (♂♀).
Dist: **JAPAN** (Honshu).

H. (E.) longifurca (Alex., 1920): TAES, 46:14 [*Eriocera*], t: Saitama (♂♀); PJS, 52:162 (1933) [n]; TSES, 3:82 (1953); Edw.: AM, (9) 8:72 [*Eriocera*] (1921); Esaki: IIJ, 202, f. 394 (♀) [*Eriocera*] (1932); IIJ, 2:1524, f. 4372 (♀) [*Eriocera*] (1950).
Dist: **JAPAN** (Honshu; Shikoku).

H. (E.) moriokana (Mats., 1916): TIJA, 2:469–71, XXV:11 (combined figure, body ♀, antennae ♂) [*Globericera*], t: Morioka; 6000 Ill. Ins. Jap.-Emp., 394, f. [*Globericera*]; Esaki: IIJ, 203, f. 396 (♂) [*Eriocera*] (1932); IIJ, 2:1525, f. 4374 (♂) [*Eriocera*] (1950); Alex.: PJS, 52:154–5 (1933) [n].

verticalis (Edw., 1921): AM, (9) 8:72, part. [*Eriocera*] [nec Wied., 1828].
Dist: **JAPAN** (Honshu).

H. (E.) nigrotrochanterata (Alex., 1932): PJS, 49:123, I:14 (w) [*Eriocera*], t: Mt. Ohdai, Yamato (♂); PJS, 83:292 (1954) [♀].
Dist: **JAPAN** (Honshu; Shikoku).

H. (E.) nipponensis (Alex. 1918): AESA, 11: 446–7 [*Eriocera*], t: Kioto (♂); EM, 3:126–7 [*Eriocera*] (1919); PJS, 83:292 (1954); Edw.: AM, (9) 8:72 [*Eriocera*] (1921).
Dist: **JAPAN** (Honshu; Shikoku).

H. (E.) stricklandi (Edw., 1921): AM, (9) 8:72, 82 [*Eriocera*], t: Japan (no exact data) (♀); Alex.: PJS, 52:340 (1933) [n]; PJS, 82:68 [s. str.] (1953) [n].

ssp. **stricklandi** (Edw., 1921)
Dist: **JAPAN** (Shikoku, etc.).

ssp. **pallidibasis** Alex. 1953: PJS, 82:68 [*stricklandi*, ssp.], t: Mt. Ishizuchi, Iyo (♀).
Dist: **JAPAN** (Shikoku).

H. (E.) subrectangularis (Alex., 1925): AM, (9)15:76–7 [*Eriocera*], t: Kofu, Kai (♂♀); PJS, 52:161, II:36 (h) (1933).
Dist: **JAPAN** (Honshu).

H. (E.) verticalis (Wied., 1828): Aussereur. zweifl. Ins., 1:56–7 [*Megistocera*], t: Java (♂); O. S.: BEZ, 30:158 [*Eriocera*] (1886); Coq.: PUNM, 21:304 [*Eriocera*] (1898); Kert.: Cat. Dipt., 2:316 [*Eriocera*] (1902); End.: ZJ, 32:35, f. U (w) [*Androclosma verticale*] (1912); Alex.: PUNM, 49:117, XLIV:25 (w) [*Eriocera*] (1915); PJS. 52:154, I:16 (w) (1933); Edw.: AM, (8) 18:253 [*Eriocera* (*Androclosma*) *verticale*] (1916); AM, (9) 8:72, text-f. 1b, 2j (h) [*Eriocera*] (1921); Brun.: RIM, 15:333 [*Eriocera*] (1918).
Dist: **JAPAN**?; **FORMOSA**; **S. ASIA**.

Genus **ATARBA** O. S., 1869

Atarba O. S.: MD, 4:46, 127–8; Brun.: FBI, 415, 434 5 (1912); RIM, 15:308–9 (1918); RIM, 17:235 (1920); Bergr.: AM, (8) 11:581 (1913); Psyche, 22:55 (1915); Alex.: MCAS, 25:897, 899 (1919); FG, 46 (1934); BCSS, 64:365, 422 (1942).
Type: *Atarba picticornis* O. S.

Subgenus **ATARBODES** Alex., 1920

Atarbodes Alex.: AESA, 13:255 [*Atarba*]; PJS, 42: 526 [*Atarba*] (1930) [key to spp.].
Type: *Atarba pallidicornis* Edw.

A. (A.) minuticornis Alex., 1930: PJS, 42:526, t: Kosugidani, Yakushima (♂); PJS, 83:292–3, III:33 (w) (1954).
Dist: **JAPAN** (Shikoku; Kyushu: Yakushima I.).

Genus **ELEPHANTOMYIA** O. S., 1859

Elephantomyia O. S.: PAP, 1859:220; MD, 4:46, 106–9 (1869); BEZ, 31:184–5 (1887); End.: ZJ, 32:63 (1912); Bergr.: AM, (8) 11:580 (1913); Brun.: RIM, 15:297–8 (1918); RIM, 17:230 (1920); Alex.: MCAS, 25:897, 898 (1919); MCAS. 38:909,

910, 952-3 (1920) [L; P]; FG, 46 (1934); BCSS, 64:365, 423 (1942); Ito: Mushi, 18:89 90 (1948) [k; key to Japanese & Formosan spp.].

Type: *Elephantomyia westwoodi* O. S. (as *Limnobiorhynchus canadensis* Westw.).

Subgenus **ELEPHANTOMYIA,** s. str.

E. (E.) dietziana Alex., 1930: PJS, 42:526-8, t: Mt. Kirishima (♂♀); TSES, 3:82 (1953); PJS, 82:297-8, V:49 (h) (1954); Ito: Mushi, 18:89, 90, f. 2A (h) (1948).

ssp. **dietziana** Alex., 1930

Dist: **JAPAN** (Honshu; Shikoku; Kyushu).

ssp. **plumbea** Alex., 1954: PJS, 82:298-9 [*dietziana*, ssp.], t: Mt. Tsurugi, Minokosi to Nagoro, Awa; Imanoyama, Tosa (♀).

Dist: **JAPAN** (Shikoku).

E. (E.) hokkaidensis Alex., 1924: PJS, 24:580-1, t: Abashiri; Kamiotoineppu; Shikaripetsu; Kamiokoppe; Ponkikin; Akan; Panketo; Shikotsu (♂♀); PJS, 83:293 (1954) [n]; Esaki: IIJ, 204, f. 397 (♀) [No Sg] (1932); IIJ, 2:1525, f. 4375 (♀) [No Sg] (1950); Ito: Mushi, 18:89-90 (1948).

Dist: **JAPAN** (Hokkaido; Honshu; Shikoku).

E. (E.) palmata Alex., 1947: AESA, 40:358-9, t: Ontake, Hida, southern Alps (♂).

Dist: **JAPAN** (Honshu).

E. (E.) subterminalis Alex., 1954: PJS, 82:299 300, V:44 (w); 50 (h), t: Mt. Tsurugi, Minokosi to Nagoro, Awa; Totidani, near Yanase, Tosa (♂♀).

Dist: **JAPAN** (Shikoku).

E. (E.) takachihoi Ito, 1948: Mushi, 18:89, 90-1, f. 1A (w); 2B (h), t: Hikosan, Buzen (♂).

Dist: **JAPAN** (Kyushu).

E. (E.) tetracantha Alex., 1954: PJS, 82:300 1, V:51 (h), t: Mt. Tsurugi, Awa (♂).

Dist: **JAPAN** (Shikoku).

Subgenus **ELEPHANTOMYODES** Alex., 1923

Elephantomyodes Alex.: AESA, 16:64 [*Elephantomyia*]; Ito: Mushi, 18:89 [*Elephantomyia*] (1948).

Type: *Elephantomyia* (*E.*) *major* Alex.

E. (E.) sophiarum Ito, 1948: Mushi, 18:90, 91-2, f. 1B (w); 2C (h), t: Inunaki-tôge, Chikuzen (♂).

Dist: **JAPAN** (Kyushu).

(To be continued)

(Entomological Laboratory of Kakogawa Branch, Received Aug. 29, 1959)

CLASSICAL FLUX IN ATOMIC NUCLEUS

Fumio FUKUZAWA

The classical fluxes in an atomic nucleus have been calculated using two optical potentials which reproduce similarly the experimental total and compound-formation cross sections of neutron. The one is uniformly-absorbing potential and the other surface-absorbing potential. Their equivalent real potentials are practically equal. In the uniformly-absorbing potential, the reaction probability distributes mainly in the core region and shows the diffraction-like pattern. In the surface-absorbing potential, as expected, the reaction probability concentrates in the diffused surface region and its maximum appear at the constant distance from the center of the nucleus independently of polar angle. It is interesting that the total reaction probabilities at different polar angles are all nearly equal for the uniformly-absorbing potential, but they decrease with decreasing polar angle for the surface-absorbing potential.

1. Introduction

The optical potential model of atomic nucleus[1] has succeeded to explain many scattering experiments. But the potentials which fit a given angular distribution are not unique, and some sets of parameters fairly well fitted are remained undistinguished[2]. To determine the parameters uniquely, it is necessary to investigate the polarization experiment and such like in addition to the scattering experiment. They have not been fully achieved. McCarthy[3] have attacked this problem from different point of view; he calculated the alpha-particle flux in an atomic nucleus using two sets of parameters well fitted and found that the reaction probabilities at a point in the far side of the nucleus differ appreciably for these two sets of parameters. In their calculation two potentials are both uniformly-absorbing type.

For nucleons, It has been found by Bjorklund and Fernbach[4] that surface-absorbing potentials can reproduce the experimental result fairly well. Further, Harada and Oda[5] have found that the uniform real potential for neutron results in the localization of the absorption near the surface. Then it is important to distinguish for nucleons whether they are subject to the uniformly-absorbing potential or the surface-absorbing potential.

In this paper we calculate classically the incident particle flux and its divergence in the nucleus using two well-fit potentials of surface-absorption and of uniform-absorption and compare their results. The methods of Eisberg, McCarthy and Spurrier[6] are followed.

2. Calculation of the Particle Flux and its Divergence

It has been shown by Eisberg et al[6] that in so far not apart from the nucleus the classical flux at a point in the potential is almost equal to the average flux by quantal calculation. Then the classical calculation is sufficient to see the main features occured in the nucleus.

For the complex potential whose real and imaginary parts are V_c and W_c respectively, the equivalent real potential which gives the same wave number at each point is given by

$$V=-\frac{1}{2}\left\{[(E-V_c)^2+W_c^2]^{1/2}-E-V_c\right\} \qquad (1)$$

and mean free path L is given by

$$\frac{1}{L}=\frac{2}{\hbar}\left\{m(V_c-E+[(E-V_c)^2+W_c^2]^{1/2})\right\}^{1/2} \qquad (2)$$

where E, m are the energy and mass of the incident particle respectively. Let the probability of finding a particle on a trajectory before entering the nucleus be unity. Then the probability of finding it at a point x, $A(x)$, where x is the coordinate along the trajectory measured from some starting point outside potential, is given by

$$A(x)=exp\left\{-\int_{-\infty}^{x}\frac{dt}{L(t)}\right\} \qquad (3)$$

where integration should be evaluated along the trajectory.

The magnitude of flux at a point x, $j(x)$, is obtained from $A(x)$ by multiplying it with the focusing factor $F(x)$ which is given by

$$F(x)=-\frac{s\Delta s}{R\Delta R}\cos\eta \qquad (4)$$

where s is the impact parameter of the trajectory under consideration, R is the distance from the axis of the nucleus parallel to the incident direction

when the incident particle reaches the point x, $\triangle s$ and $\triangle R$ are their increments respectively, and η is the angle between the direction of the flux and the incident direction.

Divergence of flux, which correspond to the reaction probability at a point, is

$$\nabla \cdot j = -\frac{j}{L} \tag{5}$$

(for details, see ref. 6))

3. Neutron Flux

The two sets of optical parameters which Amster[7] has found to fit the total and compound-formation cross sections of 14 Mev neutron for various elements are as follows:

1) Uniformly-absorbing potential:

$$V_c(r) = -V_0 f(r) \tag{6}$$

$$W_c(r) = \xi\, V_c(r)$$

$$f(r) = \begin{cases} 1 & \text{for } r \leqq R_c \\ \left[\exp\left(\frac{r-R_c}{\tau}\right) - \frac{r-R_c}{\tau}\right]^{-1} & \text{for } r \geqq R_c \end{cases}$$

2) Surface-absorbing potential:

$$V_c(r) = -V_0 f(r)$$

$$W_c(r) = -\lambda \frac{dV_c(r)}{dr} \tag{7}$$

where R_c is the core radius and say 6.0×10^{-13} cm for lead. $V_c = 40$ Mev, τ 0.85×10^{-13} cm. λ 0.47, ξ 0.1. These ponentials are shown in Figs. 1a, b.

For these potentials the classical trajectories are calculated numerically and found that they are practically equal for two cases. They are shown in Figs. 2a, b, in which the classical ray vectors whose direction is that of the momentum of a particle and whose length is $A(x)$ are also shown with arrows. l in abscissa is the angular momentum and relates with the impact parameter s of classical trajectory as

$$l^2 = \frac{2mE}{\hbar^2} s^2 \tag{8}$$

From Figs. 2a, b it is found that the main absorption occurs in the region of core for uniformly-absorbing potential and in the diffused surface region for surface-absorbing potential. The classical ray vectors near the center of the nucleus are practically same for two potentials. Sharp focusing occurs at the far side of the nucleus.

The flux $j(x)$ and the divergence of flux $\nabla \cdot j$ are represented as functions of r for different values of the polar angle θ measured from the incident direction. This representation have been employed by Eisberg et al[6] and is convenient for comparison. In Figs. 3a, b and Figs. 4a, b these quantities are shown for $\theta = 140°$, $120°$, $100°$ and $80°$.

It is found from Figs. 3a, b that main features

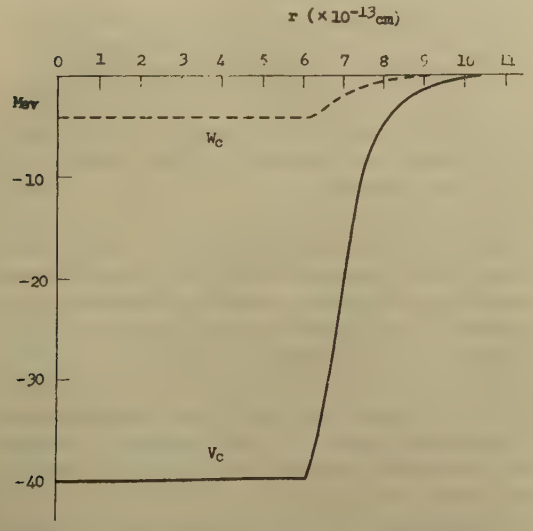


Fig. 1a. The uniformly-absorbing optical potential for 14 Mev neutron on lead, which can reproduce the experimental total and compound-formation cross sections. V_c and W_c are the real and imaginary parts of this potential respectively.

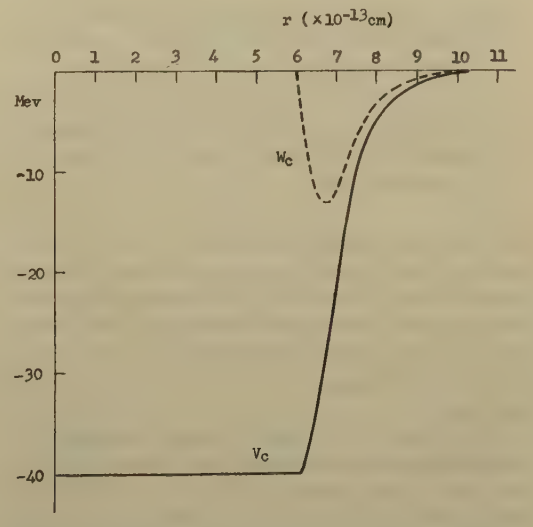


Fig. 1b. The surface-absorbing optical potential for 14 Mev neutron on lead, which can reproduce the experimental total and compound-formation cross sections. V_c and W_c are the real and imaginary parts of this potential respectively.

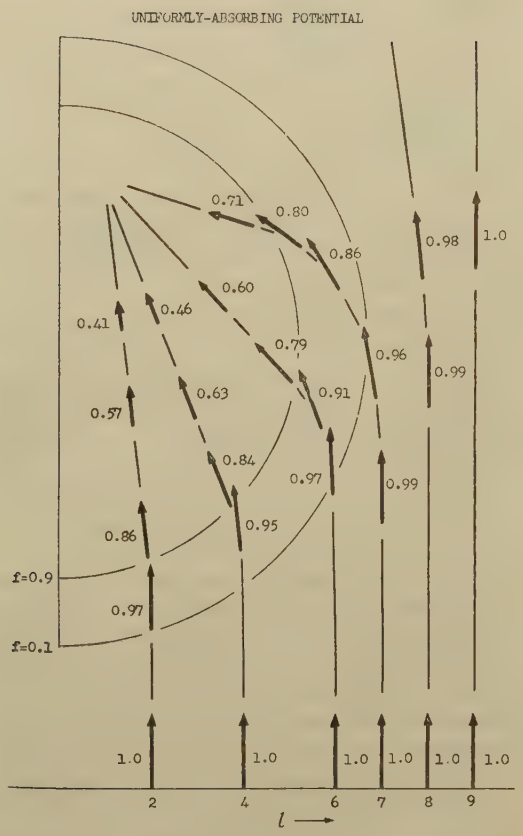


Fig. 2a. Classical trajectories of 14 Mev neutrons in the uniformly-absorbing potential. The arrows represent the classical ray vectors. l in abscissa is the angular momentum of the incident neutron. The nuclear surface is illustrated by the circles for f=0.9 and f=0.1

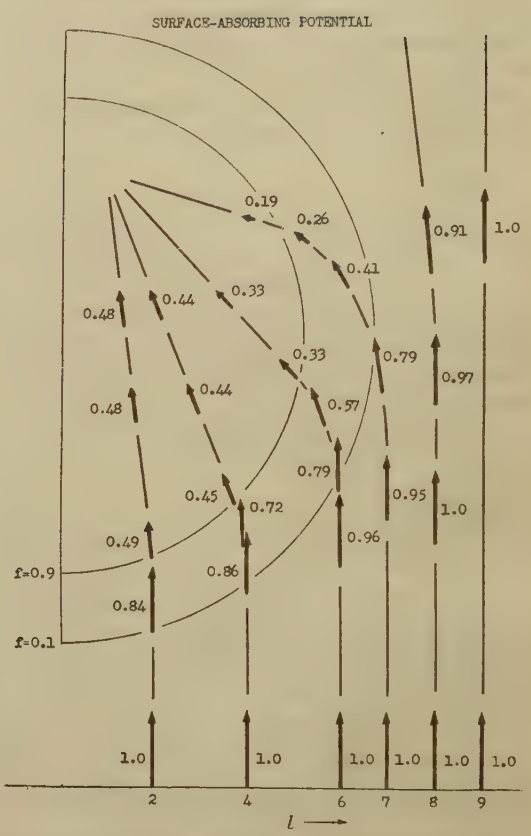


Fig. 2b. Classical trajectories of 14 Mev neutrons in the surface-absorbing potential. The arrows represent the classical ray vectors. l in abscissa is the angular momentum of the incident neutron. The nuclear surface is illustrated by the circles for f=0.9 and f=0.1

are alike for both cases except for $\theta=140^\circ$. For small r, flux is large owing to the large focusing factor and at 80° and 100° diffraction-like patterns are presented, which are not found in the calculation of 40 Mev proton[6]. Further, these patterns are more pronounced in the uniformly-absorbing potential.

From Figs. 4a, b we see that for uniformly-absorbing potential the reaction occurs mainly in the core of the nucleus and show the diffraction-like patterns as in the case of flux. This patterns appear more times with decreasing θ, i. e. with going to the far side of the nucleus. In the case of surface-absorbing potential, as expected naturally, the reation takes place in the diffused surface region without diffraction-like pattern and the position of maximum reaction probability occurs at $r=7.5\times10^{-13}$ cm independently of θ. It is interesting to note that the total reaction probabilities at each θ are all nearly equal for uniformly-absorbing patential, while for surface-absorbing potential they decrease with decreasing θ. If the diffractional pattern of the differential cross section is the reflection of some inner pattern, the meaning of this diffractional pattern is very different in origin for two potential types considered above, because the one has inner pattern and invaiant total reaction probability while the other has no inner pattern and variant total reaction probability. At this point further detailed investigation is wanted.

4. Conclusions

In this paper the uniformly-absorbing potential model and the surface-absorbing potential model of

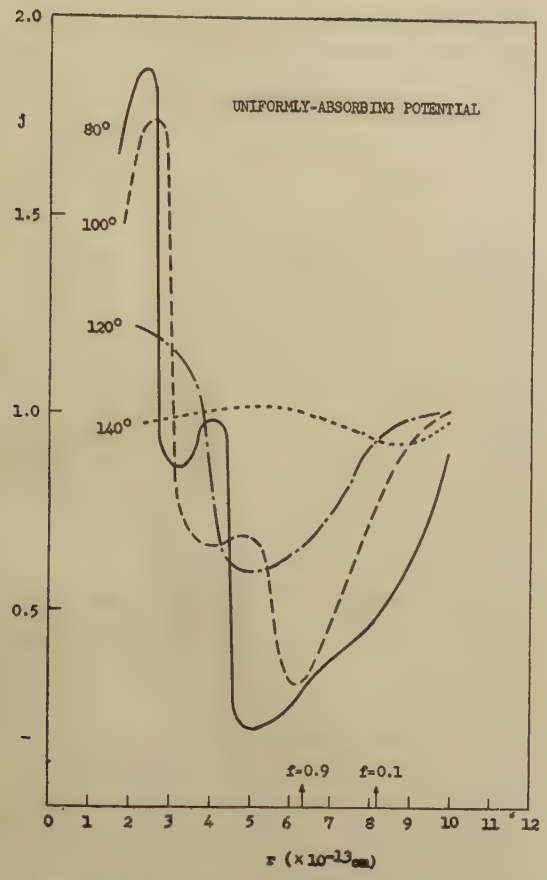


Fig. 3a. The magnitudes of the classical fluxes of 14 Mev neutrons at $\theta = 80°$, 100°, 120° and 140° in the uniformly-absorbing potential.

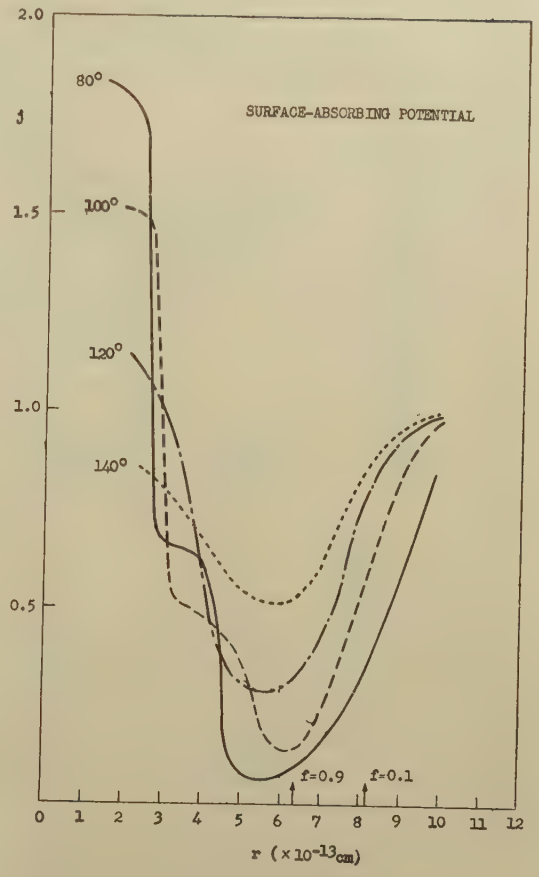


Fig. 3b. The magnitudes of the classical fluxes of 14 Mev neutrons at $\theta = 80°$, 100°, 120° and 140° in the surface-absorbing potential.

a nucleus are compared in the view of classical flux. As expected, the main absorption takes place in the core region for uniformly-absorbing potential and in the diffused surface region for surface-absorbing potential. In the uniformly-absorbing potential, large divergence of flux in the surface region which has been found by Eisberg et al[6] and by McCarthy[3] occurs only at large polar angle ($\theta = 140°$), at other polar angles the reaction takes place mainly in the core of the nucleus and show diffraction-like pattern. The total reaction probability at given polar angle decreases with decreasing polar angle for surface-absorbing potential, while for uniformly-absorbing potential it remains practically constant. These features suggest that the diffractional pattern of differential cross section is different in its origin for two different potentials. On this point further investigation are needed. Above calculations cannot be compared directly with any experimental result now available, but if the mechanism of diffractional pattern is clarified in connection with inner behavior of flux, we may hope to be able to select simply the best set of optical parameters.

(Laboratory of Physics,

Received Aug. 29, 1959)

References

1) H. Feshbach, C. E. Porter and V. F. Weisskopf, *Phys, Rev.* **96** 448 (1954)
2) A. E. Glassgold and P. J. Kellogg, *Phys. Rev.* **107** 1372 (1957)
3) I. E. McCarthy, *Nuclear Physics* **10** 583 (1959)
4) F. Bjorklund and S.Fernbach, *Phys. Rev.* **109** 1295 (1958)
5) K. Harada and N. Oda, *Prog. Theor. Phys.* **21** 260 (1959)
6) R. M. Eisberg, I.E. McCarthy and R. A.Spurrier, *Nuclear Physics* **10** 571 (1959)
7) H. J. Amster, *Phys, Rev,* **113** 911 (1959)

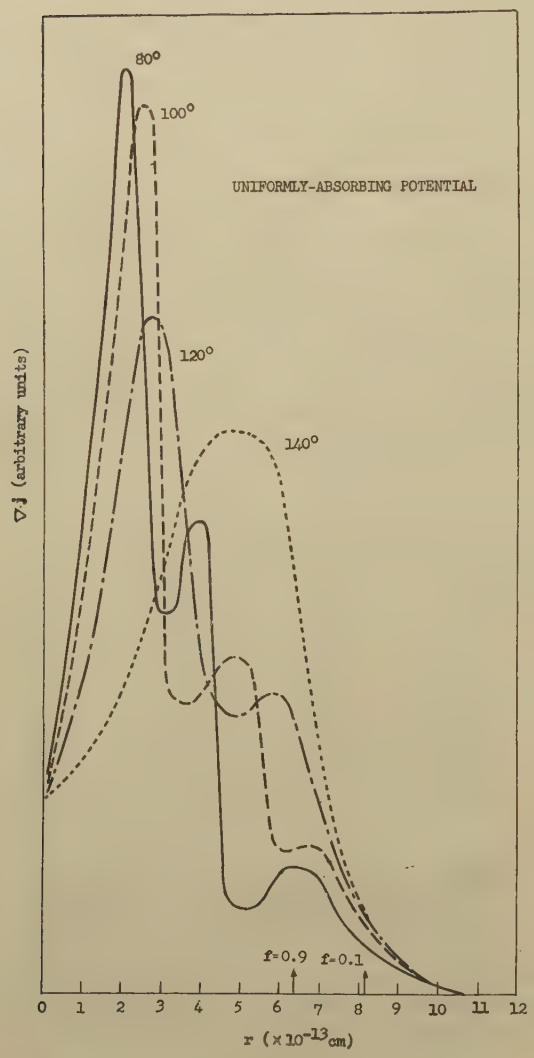


Fig. 4a. The divergences of the classical fluxes of 14 Mev neutrons at $\theta = 80°$, 100°, 120° and 140° in the uniformly-absorbing potential. Divergences take place mainly in the core region and show the diffraction-like pattern.

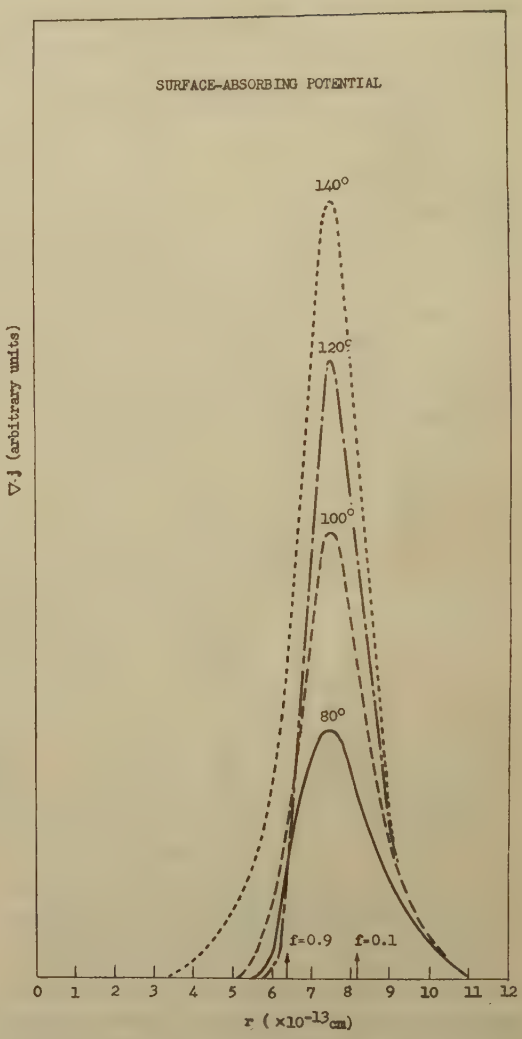


Fig. 4b. The divergences of the classical fluxes of 14 Mev neutrons at $\theta = 80°$, 100°, 120° and 140° in the surface-absorbing potential. Divergences take place mainly in the diffused surface region.

単分子膜法による卵アルブミンとブロムフエノールブルウとの結合について

石井 健三・岸本 昇三

Effect of Brom Phenol Blue in Aqueous Substrate upon the Monolayer of Ovalbumin

Kenzo Ishii and Shozo Kishimoto

緒　　論

物質相互間の Interaction を研究する一つの方法として単分子膜を利用する方法は従来より定性的或は半定量的に行われている．生体に関する反応として重要な蛋白質と他の物質との Interaction の単分子膜法によるものとして最近の例では，蛋白質と金属イオン[1]，硅酸[2]，皮なめしに関係するタンニン酸[3]，等の研究がある．何れも Substrate 溶液における物質の構造と，その上に作られた単分子膜の状態に関聯して，主として表面圧一面積（F－A）曲線を中心に論議されている．一方染色化学に関係する高分子単分子膜と色素との Interaction も，そのモデル物質を使用することにより種々の色素で研究された例もある[4),5)]．

以上の様な研究法を基礎として吾々は蛋白質と他の物質との相互作用研究の一つとして，先ず卵アルブミン単分子膜とフタレイン系の色素であるブロムフエノールブルウ（B.P.B.）との Interaction を研究した．この色素は中和滴定において著しい蛋白誤差を生じるものであり，又濾紙電気泳動法による蛋白の検出，定量に広く使用されるものでその性質を明らかにすることは興味あるものと思われる．

実　　験

単分子膜実験の装置及びその方法は以前より使用しているものである[6)]．卵アルブミンは硫安法により精製したもの，(B.P.B.) は和光純薬の特級品で表面化学的にはさしつかえある不純物はないことを確かめたのでそのまゝ使用した．先ず卵アルブミンの水溶液上の（F－A）曲線と次に色素を含んだ Substrate 溶液上のそれとを比較し，色素の濃度（10^{-6}～10^{-5}M/1），pH, Spreading time（15分～数時間）等についてその影響を検討した．なお Substrate 溶液の調製は特級塩酸，苛性ソーダ，酢酸かん衝液，又塩としては塩化ナトリウムを用いた．測定はすべて室温で行つた．

結　　果

卵アルブミンの単分子膜については多くの人達によつて繰返し研究されているが，その F-A 曲線は Spreading 溶液及び Substrate 溶液の相異によつて種々の結果が得られている．こゝでは塩を含まないものと0.125N の塩化ナトリウムの Substrate について実験した．Fig. 1，2，の A_0 は F－A 曲線の数ダイン附近の直線部分を延長することにより求めたものである．

Fig. 1 に見られる如く塩を含まない場合は pH＝3 及び中性の附近では単分子膜を全然作らないが B.P.B. の少量（1.9×10^{-6}M/1）を加えることにより pH＝3 の面積（A_0）は著しく増加する．次に塩を添加した溶液上の膜は pH＝3附近での極小はなく中性附近にのみ極小を有する．3.8×10^{-6}M/1 の B.P.B. 溶液上での A_0 の増加は pH＝4 以下の酸性側のみに見られる．更に B.P.B. の濃度を増すに従つては A_0は次第に増加する．Fig. 2に二つの濃度の場合のみを示した．一般的に中性より酸性側に A_0 の増加が見られる．低濃度の B.P.B. 溶液で A_0 の変化が見られない場合でも，Fig. 3 に示す如く低圧部分で F－A 曲線に著しい影響が見出される．即ち少量の色素によつて膜は著しく Condense したものになる．pH 4～5 附近ではこの様な効果は全然ない．以上の結果は Spreading time が30分のものである．Fig. 4 では0.125 N-NaCl, pH＝2.0及び5.06の Substrateの場合での A_0 に対する Time effect（蛋白を滴下してより圧縮を始めるまでの時間）を示した．これによると単分子膜と B.P.B. との Interaction が平衡に達するには数時間を要することがわかる．なお色素を含まない場合の蛋白の Spreading は数分間で完全になることを確かめている．

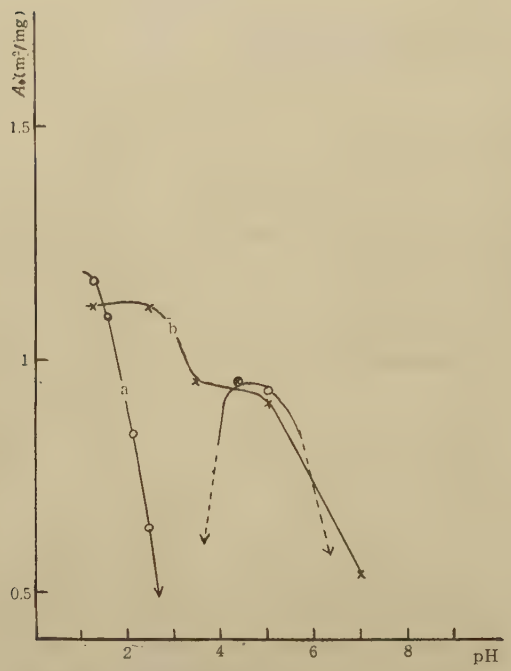


Fig. 1. Ao-pH curves.
(a) without dye
(b) 1.9×10^{-6} M/1 B.P.B.

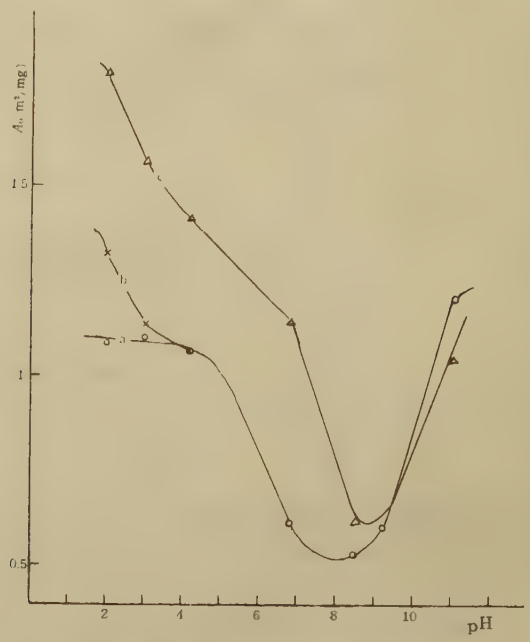
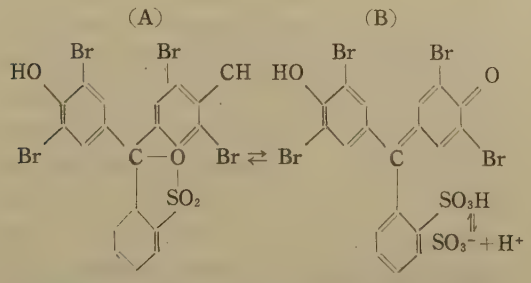


Fig. 2 A_0—pH curves. 0.125M Na Cl
(a) without dye
(b) 3.8×10^{-6} M/1 B.P.B.
(c) 1.9×10^{-5} M/1 B.P.B.

考　　察

B.P.B. の水溶液中における状態及び血清蛋白との結合については，Waldmann-Meyer 等が pH＝2.70 の場合について吸収スペクトル，透析平衡の実験によつて研究している[7]．これによると B.P.B. の水溶液は pH＝3.0～4.6で黄から青色に変りその吸収最大波長はそれぞれ4400Å，6000Å で各 Phenolic form, Quinoid form に相当している．



B.P.B. 溶液は蛋白の存在により 4.6以下の pH 域でもその量，pH の違いによつて緑色又は青色を呈する．ということは結合した B.P.B. が Quinoid 型であることを示している．又その結合は Ionic なものであり，その 6000Å の吸収曲線から蛋白上に二種の結合点のあることを見出した．

以上の様な結果を参考として単分子膜の実験結果を説明する．

先ず卵アルブミンの様な球状蛋白の単分子膜の pH—A_0 曲線は表面変性の複雑な要素を含んでいるが，Fig. 1, 2 に見られる様に A_0 が予想される値即ち約 1m²/mg より著しく小であるということは，表面に滴下された蛋白分子が溶液の内部へ溶けこんでしまつたか，或は表面に吸着されたまゝ表面変性を受けていないかの何れかである．常識的には等電点 (pH4.7～5.0)(−COO^-, −NH_3^+ 等による分子内の Interaction の一番大きい点) で A_0 は最小でその両側の pH 域では増加すべきであるが，実際は図に示す様な結果になつている．NaCl を加えることにより不完全な表面変性は pH＝3 で完全になり，中性附近では一部回復している．これ等については種々議論すべき問題を残しているがこゝでは省略する．要するに Substrate に B.P.B. が存在することによる A_0 増加は明らかにアルブミン膜に対する結合の結果である．特に膜を作らない様な条件でも少量の B.P.B. が著しい影響を与えている．この結合は pH の中性以下即ち蛋白質に正電荷 (−NH_3^+) が存在する範囲で起り，しかも全体の電荷が増すに従つて大きくなることから見て Interaction は主として電気的な力によるものと考えられる．−NH_3^+ の如き正電荷を持つ Radical が少ないペ

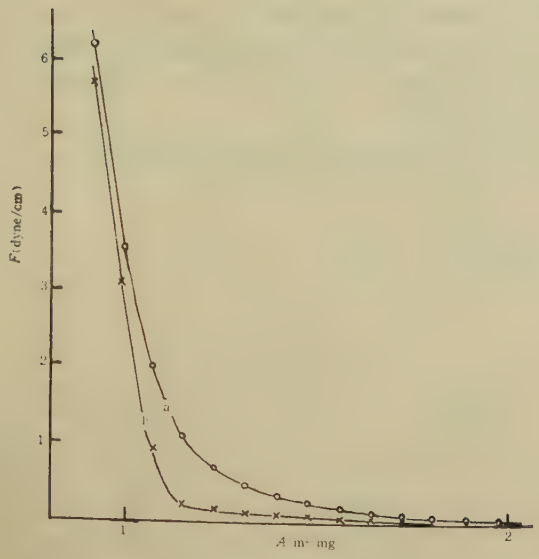


Fig. 3. F-A curves. substrate pH 1.25
(a) without B.P.B.
(b) 1.9×10^{-6} M/1 B.P.B.

プシンの様なものでは B.P.B. とは結合しないことを確かめている．又ある色素の場合には色素分子自体が溶液中でミセルを形成し，それが VAN DER WAALS 力により大きな影響を及ぼす場合があるが，B.P.B. のこの位の濃度ではミセル形成の様子はない[7]．

Substrate に NaCl を含む場合の方が同じ B.P.B. の濃度でも大きい A_0 の増加を示すがこれは B.P.B. が結合するためには乗りこさねばならないポテンシャルの山がありこれが塩の添加によつて容易になることを示している．

Fig. 3 の現象即ち B.P.B. の低濃度の場合表面圧が減少するということは次の如く考えられる．この附近の pH ではアルブミン分子は大きい正電荷を有し，しかも Substrate に存在する多数の H^+ の影響で分子内の種々の二次結合を開放し分子全体としてエントロピーの大きい，屈曲度の大きい Expand した状態で存在している．これに B.P.B. が近ずくとその負イオンによつてこれらの正電荷は打ち消され結びつくことによつてアルブミン分子の屈曲性が失われ従つて表面圧は減少し Condense するものと推察する．

結局アルブミン膜に対する B.P.B. の結合の過程は先ず色素分子の膜の下部への吸着（Fig. 3 に見られる状態）が起り続いて二次元の膜中への拡散透入を起す．この様子は Fig. 4 の通り意外に大きく数時間にわたつて顕著に認められる．この様な A_0 の変化から見てアルブミン分子中に多数の結合点があるものと相像出来る．

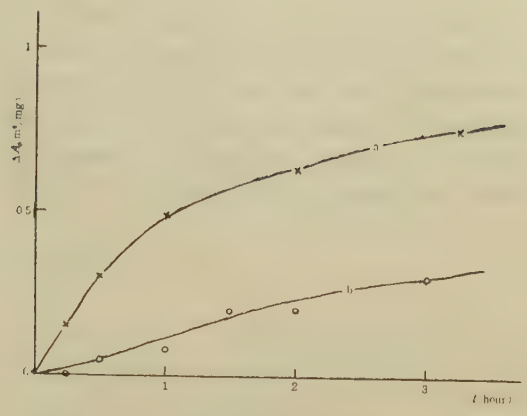


Fig. 4. △Ao-time (hour) curves.
9.3×10^{-6} M/1 B.P.B., 0.125M NaCl
(a) pH 1.97
(b) pH5.06

結　　論

1) 卵アルブミン単分子膜と B.P.B. との結合は中性より酸側の pH 域で起る．
2) アルブミン分子の正電荷が大きくなるに従つて又．B.P.B. の濃度が大になる程その面積（A_0）は増す．
3) アルブミン膜に対する B.P.B. の吸着透入には平衡に達するのに数時間を要する．

（物理化学講座，1959年 8 月31日受理）

文　　献

1) J. H. SCHULMAN and M. Z. DOGAN: *Discussions Faraday Soc.*, 1954, No. **16,** 158.
2) HOLT and J. E. L. BOWCOTT: *Biochem. J.*, **57,** 471 (1954).
3) S. C. ELLIS and K. G. A. PANKHURST: *Discussions Faraday Soc.*, 1954, No. **16,** 170.
4) M. M. ALLINGHAM, C.H. GILES and E.L. NEUSTÄDTER: *Ibid.*, 1954, No. **16,** 72.
5) M. MURAMATSU: *Bull. Chem. Soc. Japan*, **32,** 114 (1959).
6) 石井，岸本：兵庫農大研究報告，**3**（自然科学編），5(1957)
7) H. WALDMANN-MEYER and K. SCHILLING: *Arch. Biochem. Biophys.*, **64,** 291 (1956).

Summary

The interaction of ovalbumin with brom phenol blue (B.P.B.) was investigated under various pH conditions by means of surface chemical methods.

The increase of A_0 on an acid solution was attributed to the interaction mainly caused by electro-static forces between potively charged amino groups of ovalbumin and anionic B.P.B. molecules. Thus it was assumed that initially ovalbumin monolayer was solidified by the absorbed B.P.B. under the monolayer and continually expanded remarkably by the penetration of B.P.B. into the monolayer, which might be regarded as the mechanism of interaction.

(Laboratory of Physical Chemistry)

変性ペプシンの研究（補遺）*

石井 健三・安田 勝幸

Studies on the Denatured Pepsin (Supplement)

Kenzo Ishii and Katsuyuki Yasuda

緒　　言

既に報告[1]した如く，未変性の生ペプシン，並びに熱処理，アルカリ処理及びヨード化等の各種処理を施した変性ペプシンの電気伝導度を測定して，40～75°C の比伝導度（κ）—温度（T）線図を検討した結果，未変性及びある種の変性ペプシンにおいては 65°C 附近に変性点があつて．ここで κ—T 線図に折点を生じた．これらの事実を更に究明するために，前回と同じ各種試料を用いて他の二つの方法，即ち浸透圧の測定と表面拡張模様の観察とを行つた．

（その1）浸　透　圧

方　　法

浸透圧の測定は静的方法により，即ち Bull の浸透圧計[2]を作つて用いた．半透膜としては，ソーセージケーシング用の直径約 20 mm の円筒型セロハンを使用した．これを沸騰水及び稀薄な苛性ソーダ溶液で処理した後，ベルリン青の蓚酸解膠液で洩れの有無を試験して用いた．測定温度は15°Cで，浸透圧計における液面のレベル差はカセトメーターにより測定した．

結果及び考察

1. 生ペプシン：0.05，0.1及び0.2%各水溶液の浸透圧測定の結果並びにそれらの理論値は Fig. 1 に示す如くで，各濃度における実測値はいずれも理論値よりも約2倍大きい．各水溶液の pH はペプシンの等電点よりかなりへだたり，Donnan 効果は大きいものと考えられる．

次に 0.05M 塩化ナトリウム溶液を溶媒とした場合の浸透圧は，Fig. 1 の如く理論値より小さい値となる．塩の添加により Donnan 効果は減少し，溶媒のイオン強度の増大により浸透圧は低下するわけであるが，他に溶媒イオンと蛋白質との結合や蛋白質分子の会合などの影響もあるものと考えられる．

各種の pH の生ペプシン溶液の浸透圧を測定した結果は Fig. 2 に示すとおりである．即ち pH 3 において浸透圧は最小で，その前後の pH 値においては浸透圧は増大している．ペプシンの等電点は pH 3 附近と考えられるから，この点においては Donnan 効果がほとんど無いから浸透圧は最小となり，かつまたこの値は理論値にも近いものである．

2. 変性ペプシン：各種の変性処理を施したペプシンのいずれも0.1%水溶液の浸透圧を測定した．

（A）熱処理ペプシン，即ち前報[1]で述べた如く生ペプシンは65°C附近に変性点があると考えられるので，常温～65°Cの各種温度で加熱処理したものの水溶液について浸透圧を測定した．その結果は，常温及び40°C処理では差異が認められないが，50°C，60°Cと処理温度が高くなるに従つて浸透圧は増大し，65°C処理のものでは理論値の約3倍の大いさとなる．

前述の如く，κ—T線図においては65°C で折点が生じ

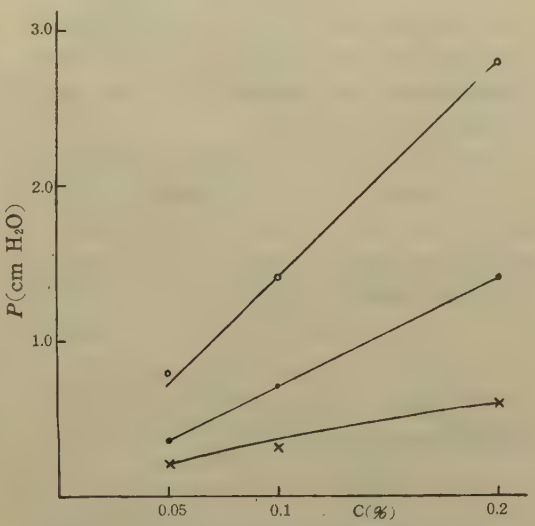


Fig. 1. Osmotic Pressures of Pepsin Solutions
○: Native pepsin
●: Theoretical value
×: Native pepsin in 0.05M NaCl

* 昭和31年4月2日，日本化学会第9年会で一部発表

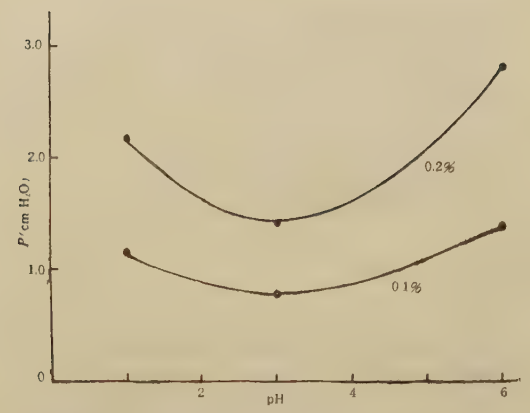


Fig. 2. Effect of pH on Osmotic Pressure

変性の完了を示しているが，変性の初期段階とでもいうべきペプチッド鎖の解きほぐれ，あるいは分裂の一部は50°C以上で始まると考えられる．

（B）アルカリ処理ペプシン，即ち pH 10で30分間処理の後，透折して減圧乾燥した試料の浸透圧は生ペプシンの場合より大きくて熱変性のものに近い値を示すが，pH 3においては溶解度は低下する．κ—T線図におけるアルカリ処理ペプシンのκ値は生ペプシンより小さい．

アルカリ処理により，ペプチッド鎖が切れ，これらがそれぞれ変性後の二次結合によつて free な極性基がふさがれた状態になつていると考えることにより，実験結果を理解できるように思われる．

（C）ヨード化ペプシン，即ちペプシンの pH 8溶液に I_2—KI 溶液を添加してヨード化し，その後透析して減圧乾燥した試料の浸透圧は生ペプシンの値の約½で，また pH 3における値もほぼそれに近く，pH の差異による変化もあまりない．

ヨード化ペプシンは一般に溶解度減少し不活性であつて，ヨード変性によつて生ずる二次的結合が進んで，安定化した状態にあるものと考えられる．

3. Donnan 効果：蛋白質の浸透圧における Donnan 効果について考察する．

$$P=P_p+P_i$$

P: 全浸透圧，P_p: 蛋白質によるもの，

P_i: Donnan 効果によるもの

P_i の近似的理論式[3]は

$$P_i=\frac{RT(ZC)^2}{4\mu} \quad \cdots\cdots(1)$$

また $$ZC=-\frac{2\mu E_mF}{RT} \quad \cdots\cdots(2)$$

Z: 蛋白1000g 当りの電荷数，

C: 蛋白濃度 g/ml, μ: 溶媒のイオン強度，

E_m:膜電位差，F: Faraday 定数

一般に Donnan 効果の存在するときには，膜の両側に電位差が生じ，溶液及び溶媒の pH が同一でない．溶液及び溶媒の pH をそれぞれ pH_1 及び pH_2 とすると

$$pH_1-pH_2=2.303\frac{E_mF}{RT} \quad \cdots\cdots(3)$$

（2）及び（3）式より

$$ZC=2\mu\frac{(pH_1-pH_2)}{2.303} \quad \cdots\cdots(4)$$

（1）及び（4）式より

$$P_i=RT\mu\frac{(pH_1-pH_2)^2}{5.304} \quad \cdots\cdots(5)$$

ところで，0.1% ペプシン水溶液の浸透圧における実測値の理論値よりのずれの大いさ，即ち P_i は約0.7 cm H_2O であつて，この値を（5）式に入れると

$$pH_1-pH_2=\pm 1.23 \quad \cdots\cdots(6)$$

となる．

浸透圧測定後の半透膜の内及び外側の液，即ち溶液及び溶媒の pH をそれぞれ pH_1 及び pH_2 とすれば，これらを実測した平均値は

$$pH_1=4.12, \quad pH_2=5.33$$

$$pH_1-pH_2=-1.21 \quad \cdots\cdots(7)$$

（6）及び（7）の両数値はほぼ一致するから，P_i の近似的理論式におおむね適合する．

（その2）拡張模様

方　　法

水面上の蛋白質薄膜の拡張模様(Expansion Pattern)についての Schaefer の研究[4]において述べられている如く，実験方法は簡単なものである．

容器の水槽の大いさは 30×15×2cm で，その周囲の枠は真鍮製，底面は黒色紙をはりつけたガラス板で，水槽の内側全面にパラフインを塗付する．水槽にのせて移動させ，液面の清掃や仕切りに用いる仕切り棒として，2枚の細長い短冊型ガラス板を用意し，これらの全表面にもパラフインを塗付する．

標示油（Indicator Oil)[5]には市販のモーターオイルを用い，これを白煙が生ずるまで加熱して酸化したものと，生のものとを適当量混ぜて標示油とした．モーターオイルは水面上での拡張性はほとんど無いが，これを酸化したものは著しく拡張して薄膜に拡がるから，両者を混ぜて適当な拡張性を有する標示油が得られる．

パラフインを塗つた水槽及び2本の仕切り棒は流水で長時間洗浄した後，水槽に蒸溜水を満たし，仕切り棒で一，二回掃いて水面を清浄にする．先を細くしたガラス棒の先端に標示油をつけて1滴水面に落とすと，油はた

ちまち水面に拡がつて薄膜となる．水槽の向こう側45度の方向より淡黄色ランプで水面を照らすと標示油の薄膜は認め易く，それの示す干渉色模様もわかる．即ち2本の仕切り棒を移動させて，その間の膜の面積を加減すれば，膜の厚さが変りその干渉縞の色調も変化する．

次にこの油膜の内側に蛋白質の薄膜を同心円状に作る．即ち清浄な白金線の先端に試料の粉末蛋白を少量つけて，これを標示油膜の中心部に接触させる．試料はただちに溶け，油膜を半径方向に押しやるような境界をなす円型の薄膜となつて水面上に拡がる．油膜の内側にできた蛋白薄膜の拡がりは，両膜の境界線で明瞭に認めることができる．この内外の両膜は同心円型に拡がつている．蛋白薄膜の拡張後，仕切り棒を用いて，蛋白膜に圧力が加わらないように注意しつつ，この膜の外周を標示油膜が密に取り囲んでいるように整えておく．

最後にこの蛋白薄膜の中心部へ前と同じ標示油を1滴落とすと，これもまた薄膜となつて拡張するが，この油膜の拡がつた形状が拡張模様である．それは蛋白質の種類によつて異なり，また同一蛋白でもその変性処理の相違に応じて，それぞれ異なる形状の拡張模様を示す．生じた拡張模様の形状も時間の経過にともなつて，界面の空気の流動などの影響により，模様が乱れたり，変形したりすることがある．水面が汚れているときれいな拡張模様は得られないから，最初の洗浄は十分に行う必要がある．

実　験　結　果

蛋白質薄膜の拡張模様は SCHAEFER が述べている如く（1）Star-like,（2）Rough circular 及び（3）Smooth circular の3種類の形状に大別できる．(Fig. 3 参照)

1. 生ペプシン粉末の拡張模様は Star-like であり，その形状は Fig. 3 (1) の如く 3～6 pointed Star であつて，まれには point 数が2の場合も生じるが，5の場合が多いようである．同一条件で実験を繰返しても point 数が一定しているとは限らず，その原因は標示油膜とペプシン薄膜との間の微妙な関係によるものと考えられる．

2. 熱処理ペプシン

（A）60°Cで30分処理の後，減圧乾燥した試料の拡張模様は生ペプシンのと変わりなく，主として 3 pointed Star となる．

（B）70°Cで30分処理した試料では前者と異なり，周囲にぎざぎざのある Rough circular となり，熱変性による構造変化の影響が明白に認められる．

3. アルカリ処理ペプシン，即ち pH 8 でそれぞれ2, 10, 30及び60分処理の後，減圧乾燥したペプシンの各拡張模様はいずれも Smooth circular となり，また pH 10で処理したものもほぼ同様となる．弱アルカリ側での処理でペプシンは変性するようで，生ペプシンの場合と全く異なる拡張模様を示す．

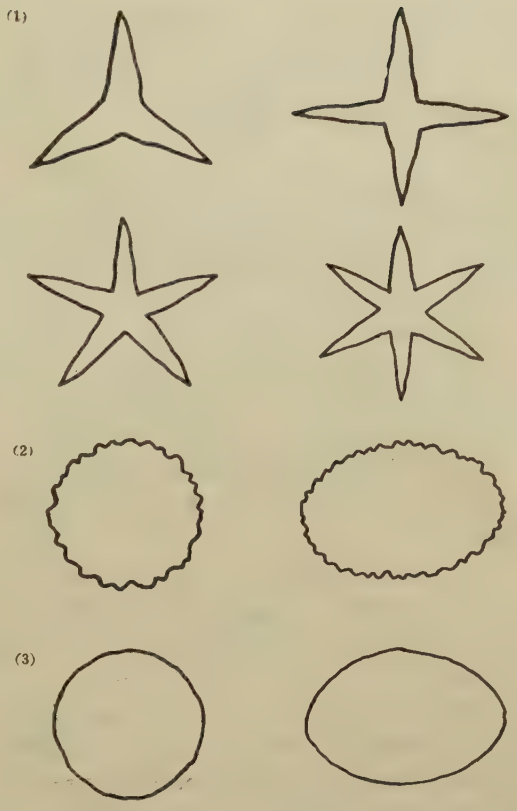


Fig. 3. General Classification of Expansion Pattern
(1): Star-like
(2): Rough circular
(3): Smooth circular

4. ヨード化ペプシン，即ちヨード処理における pH 及び時間のそれぞれ次の如く異る各種の試料（処理の後，減圧乾燥したもの）の拡張模様を調べた．

pH： 2, 4, 5, 7
処理時間：10, 30, 60分

これらの各拡張模様はいずれも生ペプシンの場合とほとんど同一の Star-like である．

次に　pH：8, 10
処理時間：2, 10, 30, 60分

これらの場合はいずれも Smooth circular である．

ヨード化ペプシンにおいて，中性及び酸性側での処理ではヨード化の程度も低く，従つて変性による構造変化

も皆無または僅小のためか，その拡張模様は生ペプシンの場合とほとんど変わりがない．一方，塩基性側でのヨード化はよく進み，活性の低下も著しく変性による構造変化も大きいためか，その拡張模様も生ペプシンと異なつている．

5. 拡張模様に及ぼす pH の影響

上述の拡張模様はいずれも蒸溜水の水面でのものであるが，次にこの水槽の水の pH を変えた場合に生じる拡張模様について述べる．

（A）pH 2 の場合，生ペプシン及びアルカリ処理はいずれも Star-like であるが，ヨード化ペプシンでは蛋白薄膜の拡がりが小さく，かつその拡張模様は前述の3基本型のいずれにも属しない不規則な形状となつた．

（B）pH 0 及び pH 1 の場合，生ペプシンもアルカリ処理ペプシンも共に Rough circular に近い拡張模様を示す．

（C）pH 8 及び pH 9 の場合，生ペプシン及びヨード化ペプシンのいずれも Star-like に近い拡張模様であるが，その形状は中性及び酸性溶液上におけるような明確なものではない．

（D）pH 12の場合，生ペプシンは Rough circular あるいは Smooth circular となる．アルカリ処理ペプシンでは pH 8 で処理のものは Smooth circular, pH10 で処理のものは Star-like となる．ヨード化ペプシンでは（A）と同様の不規則な形状である．

（E）その他

最初に生じた拡張模様の内側へ，同じ方法で更に拡張模様を作ることができる場合がある．前者を第一次，後者を第二次拡張模様と呼称することにすれば，一部の試料について実験を行つた結果，第一次と第二次とで形状の異なる拡張模様となるものもあれば，両者とも同一形状の拡張模様を生じるものもある．更にまた，場合によつては第三次拡張模様が得られることがあり，その形状についても上述と同じことがいえる．

結局，蒸溜水の水面上の拡張模様は生ペプシンでは，Star-like となり，変性ペプシンでは Rough circular または Smooth circular となる．そして水の pH が変わると拡張模様も影響を受けて，他の種類の形状に変化するものが多い．

以上の実験結果の主なものを総括すれば，Table 1 及び Table 2 に示すとおりである．

（物理化学講座，1959年 8 月31日受理）

Table 1. Expansion Pattern of Pepsin

Sample	Expansion pattern
Native	Star-like
Heat-treated (60°C, 30 min)	Star-like
Heat-treated (70°C, 30 min)	Rough circular
Alkali-treated (at pH 8)	Smooth circular
Alkali-treated (at pH 10)	Smooth circular
Iodinated (on acid side)	Star-like
Iodinated (on alkali side)	Smooth circular

Table 2. Effect of pH on Expansion Pattern

pH	Sample	Expansion pattern
0, 1	Native, Alkali-treated	Rough circular
2	Native, Alkali-treated	Star-like
	Iodinated	Irregular pattern
8, 9	Native, Iodinated	Star-like
12	Native	Rough or Smooth circular
	Alkali-treated (at pH 8)	Smooth circular
	Alkali-treated (at pH 10)	Star-like
	Iodinated	Irregular pattern

文　献

1）石井，安田：兵庫農大研究報告，2（自然科学編），7 (1955)
2）H.B. Bull and B. T. Currie: *J. Am. Chem. Soc.*, **68,** 742 (1946)
3）G. S. Adair: *Proc. Roy. Soc.*, **120A,** 573 (1928)
4）V.J. Schaefer: *J. Phys. Chem.*, **42,** 1089 (1938)
5）K.B. Blodgett: *J. Opt. Soc. Am.*, **24,** 313 (1934)

Summary

In the previous paper, it was reported that the crooked point on the conductance-temperature curve of pepsin was at about 65°C and it was the denaturation piont. In order to investigate further the denaturation of pepsin, the measurement on osmotic pressures and the observation on expansion patterns of various samples (native, heat-treated, alkali-treated and iodinated pepsin) were carried out.

Part 1. Osmotic Pressure

Osmotic pressure was measured by Bull's osmometer, a static-elevation method. Concentration of sample solution was 0.1% and its temperature 15°C.

Semipermeable membrane used in the osmometer was a sausage-casing cellophane tube (dia. 20 mm).

At the isoelectric point of pepsin (at about pH 3) osmotic pressure is minimum and at other points larger. This excess of osmotic pressure was due to DONNAN's effect and its observation value was almost in conformity with the approximate theoretical equation.

Part 2. Expansion Pattern

By SCHAEFER's method with indicator oil a cleaned platinum wire transfered a small amount of sample in the form of powder to the center area of distilled water in the tray. Then the expansion pattern was obtained on the water surface.

It varied in accordance with the kind of samples and with the effect of pH.

Expansion patterns of these samples belong to three general groupings of geometrical configuration: I) star-like, 2) rough circular, 3) smooth circular. However, irregular pattern was seen rarely in few samples.

(Laboratory of Physical Chemistry)

昭和34年12月20日 印刷
昭和34年12月25日 発行

兵庫農科大学研究報告 第4巻 第1号
自然科学編

編集兼発行 兵庫農科大学
兵庫県多紀郡篠山町

印刷所 兵庫県多紀郡篠山町郡家299
藤本印刷所
電話（篠山）320番